自己改的Recently, some works have been devoted to a IoV edge computing network, consisting of cloud computing layer and MEC layer vehicle network architectures.

solving problems of computation offloading of mobile devices in MEC or MCC-enable vehicle network architectures. Several works have focused on exploiting the benefits of computation offloading in MEC networks.

这句话语序有问题，突出的重点是任务卸载,重点应该是融合MEC和MCC，列举文献来突出两种结合的优势

Recently, some works have been devoted to an IoV edge computing network, consisting of a cloud computing layer and MEC layer vehicle network architectures. **But the Doppler effect in the high mobility of vehicles poses a challenge to V2I communication. interference caused by channel reuse in the vehicle scenario often leads to acutely poor communication quality. Vehicle equipment has a reduced tolerance for delay and transmission reliability, so higher requirements are put forward.**

首先是移动性带来的多普勒效应

信道的复用带来了干扰，尤其在高速移动情况下更难处理

车辆设备对时延与传输的可靠性容忍度降低，因此提出了更高的要求

所以有了边缘计算和云计算可以更好的提高稳定性， 面对任务卸载会遇到的这些情况，大家针对这些问题研究了什么，通过云边结合之后有什么好处，有什么优势

Aliyu et al. \cite{Ahmed2016} proposed a systematic review of MCC energy-aware issues and grouped some research works on battery energy in MCC into dynamic and nondynamic energy-aware task offloading \cite{Dai2022}. Investigate the service scenario of cooperative computation offloading in MEC-assisted service architecture, where multiple MEC servers and remote cloud offload computation-intensive tasks in a collaborative way \cite{Pang2021}, propose a hybrid transmission and reputation management strategy to accommodate the fast-changing IoV topology and to meet the low latency requirements of intelligent driving tasks

分

具体的挑战，展开这些挑战，文献的扩充

In the V2I networks, the authorized vehicles with spectrum resources can directly communicate to the RSU. However, the scarce spectrum resources appear inadequate in high-density vehicular networks \cite{Xie2020}. Zhou et al. \cite{Zhou2017} investigated dynamic sharing of the 5G spectrum and proposed a sharing architecture of DSRC and the 5G spectrum for immersive experience-driven vehicular communications. Tran et al. \cite{Tran2019} design a holistic solution for joint task offloading and resource allocation in a multi-server MEC-assisted network. As the vehicles transmitting to the same BS use different sub-bands, the up-link intra-cell interference is well mitigated. It can be see effective channel reusing is crucial \cite{Liang2021}.

When the fast-moving vehicles communicate with different MEC servers in different time slots, and each MEC can only connect with vehicles within its coverage, the generated Doppler effect has a significant influence on the small-scale fading of CSI and thereby causing fast channel variations. In other words, the CSIs used are outdated. First-order Gauss-Markov process is adopted to describe the impacts of the Doppler frequency shift on the channel in \cite{Liu2019}. So the temporal correlation coefficient is a function of the speed $$ and decreases as $$ increases, the average sum-rate degenerates as $$ grows larger, which means that a larger speed probably endows the acquisition of real-time CSI with more difficulty \cite{Chen2022}. Therein, the Bernstein approximation method has commonly been used to deal with this difficult handling non-convex problem \cite{Wang2015}. To deal with the interference constraint, the probability constraint is constructed to depress the uncertain co-channel interference. And the Bernstein approximation method is used to transform it into a solvable closed form. To deal with the outage probability constraint, we assume the CSIs are obtained through channel estimation \cite{Xiao2020}. Therefore, the outage constraint is transformed according to the Bernstein-type inequality to make it a deterministic optimization problem. Based on the characteristics of our constraints, Bernstein method is also used in this paper.

**时延也是一个关键的指标，可以建立概率约束来描述，而且使用了积分变换可以求解。可以列举文献，Considering that the exact expression shown for the contains the exponential integral function, to make it tractable, consider an approximate closed-form expression such that the computational complexity can be reduced.哪些使用了积分变换进行求解**

**Moreover, due to the outstanding performance in low communication delay and** computing **delay,** Li et al. **introduce the outage probability constraint to guarantee the reliability of vehicular links**\cite{Li2020}**. Considering that the exact expression contains the exponential integral function, to make it tractable, consider an approximate closed-form expression such that the computational complexity can be reduced.**

Some papers focused on the problem of computation offloading in the multiple users’ scenario. Tan and Hu \cite{Tan2018} designed a joint communication, caching and computing problem for achieving the operational excellence and the cost efficiency of the vehicular networks. \cite{Wang2020} formulated the problem as a generalized NE problem and presented a game theory algorithm to analysis the equilibrium problem. In summary, most of the existing works did not consider a holistic approach that jointly power control and the computing resource allocation in a multi-vehicles, multi-MEC system as considered in this paper.

**怎么解决联合优化的问题**

It is assumed in \cite{Wang2020} that the vehicles use a constant transmit power while our approach optimizes vehicle’s transmit power. However, it seems like a new problem because the objective function is difficult to handle. Nemirovski and Shapiro have proposed a convex approximation approach in \cite{Nemirovski2007} that can solve it. **Aiming at the non-convex of the problem with two variables, Some research decouples the original problem into two subproblems and deploys the block coordinate descent (BCD).**

**In this paper, a distributed robust power control and nonuniform price bargaining algorithm is proposed for the D2D-based vehicular networks with channel uncertainty and co-channel interference. The interference management is effectively realized by the allocation of power and price, and user QoS is also guaranteed in the framework. The main contributions are summarized as follows:**

**Generally, for the low-speed V2I communication case, the Doppler effect is not noticeable, thereby being ignored, but the high mobility of vehicles poses a challenge to V2I communication. it is analyzed that the original stochastic optimization problem with two variables can be transformed into a deterministic non-convex optimization problem. It is likely to bring a new difficulty.**

**In this paper, The main contributions are summarized as follows:**

**Our proposed ICCRA strategy considers joint co-layer and cross-layer computation and communication resources to guarantee the various task requirements.**

**Due to coupling between multiple variables a joint optimization scheme is proposed to maximize the minimum average secrecy rate among all IRs in the worst case. The trajectory, jamming power, and transmission power are jointly optimized in the scheme. However, the three optimization variables are coupled in the objective function and constraints, the bounded location error model constraint of Eves, and the NFZs constraint, which makes the problem intractable. We apply the slack variables, successive convex approximation (SCA) method and S-Procedure to transform the original problem into two solvable convex subproblems.**

**In this paper, a robust power control and task offloading algorithm is proposed for the cloud assisted MEC in vehicular networks with highly dynamic vehicles. The communication delay and computing delay are guaranteed by probabilistic constraints, and vehicle QoS is also guaranteed in the framework. The main contributions of this paper include the following aspects:**

**贡献点**

* 不同于以往的研究新意是什么，什么被提出，考虑解决了什么，建立了什么样的模型
* 云边协同的好处是什么
* 不同于以往的研究，本文研究了云计算与边缘计算协同情况下的车联网，提出了鲁棒的功率控制算法与计算资源分配方案，考虑了低时延与高可靠性的网络结构，建立了(C-MEC)模型辅助车辆完成任务卸载并保证通信的质量。

**environment**

**Our proposed algorithm considers cross-layer computation and communication resources to guarantee the vehicle QoS and various task requirements under C-MEC vehicular networks.**

**Considering the channel uncertainty caused by the high-speed movement of vehicles in the scenario of the Internet of Vehicles, the first-order Markov process is introduced. A reasonable and feasible IoV network environment is constructed to more realistically describe the dynamic characteristics of the Internet of Vehicles. The Bernstein approximation method previously used in interference constraints is improved and generalized, and it is applied to the matrix form of interruption probability to deal with non-convex outage constraint in large-scale dynamic vehicle network environments to ensure the quality of network communication services**

**C-MEC vehicular networks.这种网络结构的提出，结合了云计算与边缘计算的优势，既保证了**

**We present a C-MEC vehicular networks for computation ofﬂoading architecture. For MEC layer, which has moderate computation capacity and deploys close to networks, can be used to assist the vehicles. Cloud computing layer, can be used to process the large-scale, delay-insensitive data that MEC layer can not process.**

系统模型就不要再解释了，直接说我建立了什么样的模型

原来的In this paper, we consider a **C-MEC vehicular networks** in Fig. 1. Numerous vehicle-to-RSU (V2I) cells underlay a macro cell. In which each RSU is equipped with a MEC server to provide computation offloading services to the vehicles. To avoid inter-cell interference, the time division multiple access (TDMA) communication technology is adopted. Time resource is divided into multi-frames, and each frame is divided into several time slots. Different vehicles access its time slots when they communicate with the RSU, and signal transmission in different time slots will produce no interference [10]. We denote the set of vehicles and MEC servers in the mobile system as $$ and $

**TDMA的引入要重点介绍一下，引入的必要性**

**In VANETs, Time Division Multiple Access (TDMA) is widely used and assigns the collision-free spectrum resources to different vehicles by a ﬂexible time-slot scheduling [12]. There are some ﬂexible TDMA-based protocols which avoid the wastage and shortage of the ﬁxed-length time slot [13], [14]. In [13], the frame length is dynamically doubled or halved based on the vehicle density, but the overhead is very high. In [14], each time frame length is adjusted frame by frame to ensure the maximum time slot utilization. Since this strategy needs the estimated number of vehicles, it’s hard to realize in highly dynamic vehicle density. In fact, when it comes to large-scale system optimization (e.g., clusters-based system), these protocols are improper since global performance optimization requires a high degree of synergy. Hence, the uniﬁed-length time slots are used to achieve the synchronous slot handover in all clusters. To overcome the limitations of the ﬁxed-length slot and guarantee the fairness of resource allocation, this paper proposes a round-robin time scheduling method based on node ID.**

**Since the cluster system adopts TDMA technology, each CH can only communicate with one CM of its cluster in one time slot, and other CMs of the cluster communicate with their CH sequentially based on the previously allocated time sequence. Given all clusters use the same time scheduling strategy, their effective links coexist and are synchronously switched on any one time slot. The vehicles possess two interfaces: IEEE 802.11p and LTE. CMs can only communicate with their CH via IEEE 802.11p, while CHs communicate with both their CMs via IEEE 802.11p and the BS via LTE. The reference time scale of the packet transmission is of milliseconds. Assume the variation of the vehicles’ speed is negligible within the reference time interval, and all signals from the transmitters to the receivers are transmitted through the line of sight (LOS) propagation.**

**In this paper, we propose to divide multiple geographic zones (i.e., in Fig. 1) within the RSU’s coverage, and select part of vehicles to form a mobile edge server within each zone for cooperative computing.**

**In the vehicular network layer, we can divide the road into corresponding M segments based on the coverage areas of M RSUs, e.g., segment m corresponds to the coverage of RSU Rm.**

**road network is divided into multiple sub-areas and each one is assumed to be covered by one type of wireless interfaces, such as RSUs.**

**the road network is divided into multiple sub-areas, and each is assumed to be covered by one type of wireless interfaces, such as RSUs.**

**我们提出了一个三层结构的C-MEC车辆网络，分别为车辆层，MEC层，cloud层，道路被分割成多个物理区域，并且每个都包含于一个路边单元。任务卸载过程的细节如下：首先**

**In this work, the road network is divided into multiple geographic zones within the RSU’s coverage in Fig. 1, which is composed of the MEC layer, and the cloud computing layer hierarchical architecture of computation ofﬂoading,** numerous vehicle-to-RSU (V2I) cells underlay a macro cell. In which each RSU is equipped with a MEC server to provide computation offloading services to the vehicles. **The detailed ofﬂoading process is described as follows. Firstly, the vehicles ofﬂoad request messages by the wireless interface, which includes required communication resources, the task ID and submission time, and the expected service delay of the task to the cloud. Secondly, the MEC server makes scheduling according to the received request messages, including the task upload server and task computation server. Finally, after task upload, the task waits in the computation queue until one of the processors is available.**

**The detailed ofﬂoading process is described as follows. Firstly, the roadside users ofﬂoad request messages that include the required communication/computation resources, the available transmission power, and the expected service delay of the task to the RSU.**

**Then, the RSU makes scheduling according to the received request messages. The scheduling decision contains the user’s ID, the server’s ID, and the allocated transmission bandwidth and computing frequency. Since the request messages and scheduling messages are of small size, the time and energy consumption in making scheduling decisions can be ignored.** **Finally, the scheduling decision is returned back to the users, which will ofﬂoad their tasks by following the scheduling decision.**

**Firstly, the vehicles ofﬂoad request messages by the wireless interface, which includes required communication resources, the task ID and submission time, and the maximum tolerable service times of the task to the cloud. Second, the MEC server makes scheduling according to the received request messages, including the task upload server and task computation server. Finally, after the task is uploaded, the task waits in the compute queue until the server's processor processes it.**

**Finally, after task upload, the task waits in the computation queue until one of the processors is available.**

**First, the beacon message periodically broadcast by the vehicles is monitored by the wireless interface, which includes task submission information, such as task ID and submission time, and mobility features, such as the velocity and driving direction. By receiving the collected information from the wired connected wireless interface, the MEC server maintains a submission queue for storing these new tasks. Second, the MEC server makes the scheduling decision of each task in the submission queue, including task upload server, task migration server and task computation server. Third, if the task upload server is equal to the dwelling server, the task ID will be pushed into the upload queue and the vehicle waits for uploading task data. Otherwise, the vehicle keeps silence until driving into the coverage of determined task upload server. Fourth, after task upload, the MEC server will check whether the task computation server is equal to the task upload server. If so, the task is then pushed into the computation queue in the local server. Otherwise, the task is pushed into the migration queue and migrated to the determined task computation server. Fifth, after task migration, the task waits in the computation queue until one of the processor is available. In this article, the cost of retrieving the computation result is not considered since the data size of computation result is always much smaller the task itself, which is commonly adopted in related literatures [26].**

**REMARK**

**In this work, we only consider the simpliﬁed single-segment case in order to derive a tractable solution. The more complicated multi-segment case is beyond the scope of this paper and will be investigated in future works. Nevertheless, the proposed solution can be easily extended to the multi-segment scenario by adopting a time-slot model. That is, the number of vehicles in each segment remains constant within a slot and varies across different slots. Hence, the proposed solution can be applied for the optimization of workload ofﬂoading within each segment in a slot-by-slot fashion.**

**In this paper, we only consider the simplified single-segment case in order to derive a tractable solution. The more complicated multi-segment case is beyond the scope of this paper and will be investigated in future works. Nevertheless, the proposed solution can be easily extended to the multi-segment scenario by adopting a** time division multiple access communication technology**. That is, the number of vehicles in each segment remains constant within a slot and varies across different slots. Hence,** time resource is divided into multi-frames, and each frame is divided into several time slots. Different vehicles access its time slots when they communicate with the RSU**.**

**相关工作之后做一个总结，总结一下我做什么了他们没有做的**

**一个定性的解释，说明du是不是正比于cu，放在提出的问题前面**

**乘子的迭代图**

Recently, some works have been devoted to an IoV edge computing network, consisting of a cloud computing layer and MEC layer vehicle network architectures. In \cite{Zhou2019}, a hierarchical computing framework for vehicular networks proposed which is composed of the control layer, the vehicular edge computing server layer and the vehicular network layer. Dai et al. Investigate the service scenario of cooperative computation offloading in MEC-assisted service architecture, where multiple MEC servers and remote cloud offload computation-intensive tasks in a collaborative way \cite{Dai2022}. Some papers focused on the problem of computation offloading in the C-MEC vehicular network scenario. Tan and Hu designed a joint communication, caching and computing problem for achieving the operational excellence and cost efficiency of vehicular networks \cite{Tan2018}. \citet{Wang2020} formulated the problem as a generalized NE problem and presented a game theory algorithm to analyze the equilibrium problem. \citet{Wang2022} develop a distributed clustering mechanism designed to classify vehicles into multiple cooperative edge servers and maximize the total revenue in the entire scheduling duration. \citet{Li2023} construct an analytical model of the service cache at the edge of the vehicle, mainly considering the computational task offloading and task interdependence between RSUs. In summary, most of the existing works only optimized one of the two indexes that power control and the computing resource allocation. It is assumed in some research that the vehicles use a constant transmit power while our approach optimizes the vehicle’s transmit power and the computing resource allocation in a multi-vehicles, multi-MEC system as considered. In this case, it caused a new problem because the objective function is difficult to handle. Nemirovski and Shapiro have proposed a convex approximation approach that can solve it \cite{Nemirovski2007}. Aiming at the non-convex of the problem with two variables, some research decouples the original problem into two subproblems and deploys the block coordinate descent (BCD).

Unlike the traditional mobile communications networks with low mobility the Doppler effect in the high mobility of vehicles poses a challenge to C-MEC communication, when the fast-moving vehicles communicate with different MEC servers, the deterministic channel state information (CSI) is no longer sufficient to describe the channel state in network scenarios with dynamic characteristics, the generated Doppler effect has a significant influence on the small-scale fading of CSI and thereby causing fast channel variations. In other words, the CSIs used are outdated. The First-order Gauss-Markov process is adopted to describe the impacts of the Doppler frequency shift on the channel in \cite{Liu2019}. Moreover, in order to the outstanding performance with low communication delay and computing delays, vehicle equipment has a reduced tolerance for delay and transmission reliability, so higher requirements are put forward. Li et al. introduce the outage probability constraint to guarantee the reliability of vehicular links \cite{Li2020}. Considering that the exact expression contains the exponential integral function, to make it tractable, it is necessary to consider an approximate closed-form expression such that the computational complexity can be reduced.

信道复用问题

In the C-MEC vehicular networks, authorized vehicles with spectrum resources can directly communicate to the RSU. However, the scarce spectrum resources appear inadequate in high-density vehicular networks \cite{Xie2020}. Zhou et al. investigated dynamic sharing of the 5G spectrum and proposed a sharing architecture of DSRC and the 5G spectrum for immersive experience-driven vehicular communications \cite{Zhou2017}. Tran et al. design a holistic solution for joint task offloading and resource allocation in a multi-server MEC-assisted network \cite{Tran2019}. It can be see effective channel reusing is crucial when the spectrum resources are scarce \cite{Liang2021}. But this can cause problems with interference, interference caused by channel reuse in the vehicle communication scenario often leads to acutely poor communication quality. Then, to deal with the interference constraint, the probability constraint is constructed to depress the uncertain co-channel interference, the Bernstein approximation method is used to transform it into a solvable closed form, the method has commonly been used to deal with the difficult handling non-convex problem \cite{Wang2015}. To deal with the outage probability constraint, Xiao et al. assume the CSIs are obtained through channel estimation \cite{Xiao2020}. Therefore, the outage constraint is transformed according to the Bernstein-type inequality to make it a deterministic optimization problem \cite{Chen2022}. Based on the characteristics of our constraints, the Bernstein method is also used in this paper.

Aliyu et al. proposed a systematic review of MCC energy-aware issues and grouped some research works on battery energy in MCC into dynamic and nondynamic energy-aware task offloading \cite{Dai2022}.

Pang et al. propose a hybrid transmission and reputation management strategy to accommodate the fast-changing IoV topology and to meet the low latency requirements of intelligent driving tasks.

As the vehicles transmitting to the same BS use different sub-bands, the up-link intra-cell interference is well mitigated.

Recently, some works have been devoted to an IoV edge computing network, consisting of a UAV- Assisted vehicular networks architectures.

无人机的作用，空中基站，与边缘服务器进行协作

轨迹规划与双向车道

联想效率与复杂的分式规划，使用丁克尔巴赫方法

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **天翼云盘** | **阿里云盘** | **115网盘** | **百度云** | **OneDrive** | **企业微信微盘** |
| **空间** | **60G(2.1T＋1.1T)** | **100G(904G＋1T)** | **15G(2T)** | **100G(2T)** | **10G(15G)** | **20G(100G)** |
| **限速** | **否** | **否** | **115k/s** | **5k/s** | **否** | **否** |
| **单日流量** | **2G** | **500G？** |  |  | **无** |  |
| **单次转存** | **1000个** | **500个** | **500个** | **500个** | **无** |  |
| **回收站** | **10天** | **10天** | **15天** | **10天** | **30天** | **30天** |
| **批量上传数** |  |  |  | **500个** | **无** | **2000** |
| **秒上传** | **支持** | **支持** | **支持** | **支持** | **不支持** | **支持** |
| **大文件** | **2G** | **100G** | **5G** | **4G** | **10G＋** | **5G＋** |
| **密码箱** |  | **50G** |  | **100G** | **3个文件** | **无** |
| **视频播放** | **原画** | **720P/1080P限免** | **不支持** | **720P限免** | **同步后原画** | **同步后原画** |