**Ⅱ MEC-enable vehicle network**

**A.系统模型**

In this paper, We consider A IoV edge computing network, consisting of a cloud computing layer, MEC layer, as shown in Fig. 1. 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。

《Reinforcement Learning》。numerous vehicle-to-RSU (V2I) cells underlay a 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 VUEs access its time slots when they communicate with the RSU, and signal transmission in different time slots will produce no interference [10].《su03》.We denote the set of vehicles and MEC servers in the mobile system as V = {1, 2,...,V} and M = {1, 2,...,M}, respectively. 《joint》Some notations are given in Table II.

**B. 通信模型**

Different from the traditional cellular communication,Due to the fast mobility of vehicles, their CSIs are hard to be estimated precisely. In particular, RSU can only achieve the accurate knowledge of large-scale fading $ $ of vehicular to RSU links while the small-scale fading $$ is greatly influenced by the fast channel variations caused by the Doppler effect. We assume that such CSIs is obtained through channel estimation 《eeh》, Therefore, we model the small-scale fading channel estimation of $$ by using the first-order Gauss–Markov process [27] in each TTI as follows.《小帅》



we assume that the estimated channel gain denotes the estimate of and is exponentially distributed with unit mean [33]. Furthermore, represents the correlation coefficient over v → m link, and stands for the channel gain and follows a complex Gaussian distribution ，and independent and uncorrelated of . The coefficient (0 << 1) quantifies the channel correlation between the two consecutive time slots and we assume that time correlation coefficient is same for all VUEs. According to the Jakes statistical model for the fading channel [28], is given as

(4) where is the zero-order Bessel function of the first kind.

= is the maximum Doppler frequency, where indicates the vehicle speed, indicates the carrier frequency at 5.9 Ghz, and ， is a period feedback latency. erally,both transmitter vehicles and RSU can know the accurate .

Based on the aforementioned discussion, the mobile V2I channel power gain of the effective links and interference links in kth time slot from ith transmitter to jth receiver can be expressed as a shared expression:

Where$ $ ，$ $, $$and $ $denotes the kth time slot large-scale fading effects including shadow-fading and path loss from ith transmitter to jth receiver on the road section。Moreover, $ $is an observed value. $$ denotes an exponential random variable with parameter $$

To improve the spectrum utilization and realize multi-vehicles joint communication, V2I communications reuse the same uplink channel. In this case, the Signal-to-Interference-plus-Noise Ratio (SINR) from vehicle$ $to RSU can be formulated as, $ $where denotes the transmit power of the jth vehicles，where is the background noise。Therefore, the deterministic equivalent transmission rate of VUEs calculated by Shannon’s theorem is$ $,Hence, the transmission time of vehicle u when sending its task input$ $in the uplink can be calculated as, $ $， where W is the bandwidth of the reused channel. Therefore, the upload time of each V2I link can be formulated as$ $,And$ $is the amount of input data including system settings, program codes, and input parameters ，which is necessary to transfer the program execution.

Communication delay is another significant index that affects the performance of wireless networks. The packets to V2I receivers must be in the queue before they transmit at the speed of$ $. It is assumed that the process of a packet arriving at the ith V2I receiver is a Poisson process with parameter$ $, and the length of the data packet obeys the exponential distribution of parameter$ $. Under the M/M/1 model [34], the relationship between the expected delay and transmission rate of the ith V2I links can be expressed as $$.

**C. 计算资源分配**

vehicle computation task

we consider that each vehicle$ $has one different computation task at a time. denoted as$ $, [cycles] specifies the workload, i.e., the amount of computation to accomplish the task,that is atomic and cannot be divided into subtasks. The values of$ $can be obtained through carefully profiling of the task execution [7],[32]. Each task should be offloaded to the MEC server and then transmission to the cloud server. By offloading the computation task to the MEC server, the vehicles would get more computing resources,however, it would consume additional time for sending the task input in the uplink.

The MEC server at each RSU is able to provide computation offloading service to a vehicle at a time slot .The computing resources are quantified by the fixed rate$ $, expressed in terms of number of CPU cycles/s. the vehicle n uploads the input data of task to the nearest RSU，the RSU process the small-scale, delay-sensitive data first, then the RSU forward the remaining data to the remote cloud server. the cloud is able to provide computation offloading service to multiple RSU concurrently. The computing resources made available by cloud to be shared among the associating users are quantified by the computational rate , it is still expressed in terms of number of CPU cycles/s ,Thus, the latency for computing offloading can be written as$ $.

**效用函数**

Given the computing resource allocation$ $, the total delay experienced by vehicle u when offloading its task is given by$ $. The transmission latency between RSU and cloud server is defined as$ $, usually it is set to a fix value. 《Reinforcement Learning》 so the relative improvement in task completion time is characterized by $$,where$ $ is the maximum tolerable threshold of the task completion time，If a task can be completed ahead of deadline$ $, the vehicle can get a higher utility, otherwise, it will produce the corresponding loss.Therefore, we define the offloading utility of vehicle u as, $ $denote offloading time cost utilities at a unit .

**优化问题的制定**

The joint task ofﬂoading and resource allocation will be formulated as an optimization problem in this section. And the goal is to obtain the minimum total system cost composed of latency and transmission rate for all vehicles in the networks. For a given uplink power allocation P, and computing resource allocation F, we define the system utility as the weighted-sum of all the users’ offloading utilities, $$This utility means getting a more enormous execution time utility with a minor upload time cost ,We now formulate the Joint Resource Allocation and Task Offloading problem as a system utility maximization problem, i.e. The robust optimization problem is formulated as follows

优化函数 *max*

3

4

where U denotes the network utility,The constraints in the formulation above can be explained as follows:

Constraints (8c) is used to guarantee the QoS requirements of VUEs,however,due to Large amount of computation caused by time varying network topologies，the real-time SINR is hard to obtain in vehicular communication scenario, and it can be replaced with the long-term SINR since the CSI feedback time interval is very small.$$denotes the average SINR of the ith V2I link when a small CSI feedback time interval is used，In order to ensure that the task is successfully offloaded to the RSU,its SINR should be guaranteed to be no less than the SINR threshold.《su02》$$ is the SINR threshold for successful detecting the V2I communication.$$ defines the probability of the input，In this case, we introduce the outage probability constraint (8c) to guarantee the reliability of vehicular links.《小帅》Di,max is the upper delay bound of the ith D2D pair in the process of data transmission. $$,$ $ are the outage probability thresholds of SINR and delay constraint respectively, where $$ .constraints (12g) state that each MEC server must allocate a positive computing resource to each user associated with it and that the total computing resources allocated to all the associated users must not excess the server’s computing capacity.C6 states that the number of applications served by a particular edge cloud should be within its capacity.C2 denote the total latency of communication and computing should be guaranteed to be no less than the time threshold , $$ is the maximum transmit power of the transmit vehicle in vehicle communication network,and the transmit power is greater than zero.

**问题的分解**

**A．Uplink power allocation**

In this section, we proposed a BCD-based algorithm to solve the problem (7). The BCD method enables the complex original problem to be decomposed into a series of simpler subproblems [13]. Motivated by this fact, all variables are divided into two blocks and optimized alternatively.

Robust power control Optimization Algorithm

By fixing F, the problem (7) can be transformed into the following problem.

优化函数 *max*

4

Successive Convex Approximation of the Objective Function

Since the original problem is a non-convex and NP-hard because of the logarithmic function in the objective function, here, the method of successive convex approximation is adopted to relax the original problem and make objective function solvable. We can use the lower bound to approach the original function as follows.

Each term of (5) can be represented by $ $ through successive convex approximation, where $ $ and $ $ can be chosen as $ $, $$, $$=1, $ =0, and each term of objective function can be written as Follows

it is still hard to directly calculation because of fractional from of SINR, we use variable substitution, i.e. $ $,$ $, then

**Extension to Error Channel Gain With Unbounded Support 处理概率约束 xie02**

中断概率约束表示为

It is obvious that the constraint (6) includes uncertainties and the objective function is a non-convex problem in (5). The objective function and constraints are difficult to deal with when determining the optimal solutions. it is necessary to design an algorithm with lower complexity to solve the problem. In this paper, For the uncertain channel gain. Considering the fast fading, Two common forms are adopted to describe the uncertainty mentioned above, i.e. the statistical constraints and deterministic constraints. to pursue a simple form of (d),a matrix form is introduced,the general form the channel gain is described as,

Where$ $,Furthermore, the Bernstein method is adopted to approximate the probability constraint with channel uncertainty

Theorem 1: The outage probability of all cochannel V2I links$ $

is reformulated as the separable constraints (26)

Where $$, these parameters (i. e., $$ and $$ )are deduced to be positive in Appendix A.Suppose that the truncated distributions of$ $have bounded supports$ $，$ $is an estimate of$ $,Introduce constants $ $,$ $ to normalize the supports to$ $ as follows,

In the last term of (15), the variables$ $are coupled nonlinearly. Hence, directly finding an acceptably good solution to (9) by the Bernstein method is time consuming when the K increases and the number of vehicles is large. Therefore, it is necessary to Introduced a l2-norm approximate problem for any$ $，Hence, The last term in (12) containing l2-norm of the vector is further approximated by$ $ , Based on these, the constraint in (12) is further formulated as$ $with lower complexity and higher reliability.

The constraint (9a) can be handled by an Integral transformation method,According to constraint (9a)), where$ $,$ $,$ $,$$ we can get the feasible power region of the communication delay probability as follows

The proof of the feasible region can be found in Appendix B

In summary, we can obtain a deterministic optimization problem of robust power allocation by transforming the objective function, outage probability constraints, delay constraints. It is expressed as,

P1

2

4

OPTIMAL POWER CONTROL AND PRICING SOLUTIONS

Optimal Power Control Algorithm

To pursue an iterative algorithm for solving the problem,Lagrange dual decomposition technique [39] is used to maximize the lower bound of the original objective under given coefficients Xi and Yi. It’s noted that these two coefficients should be updated to guarantee amonotonic increase in the lower bound performance.

Hence, the Lagrangian function of (17) under fixed coefficients Xi and Yi can be expressed as

Maximization of the inner dual function,D μ, λ , can be performed by determining the stationary point of (27) with respect to λ and ˜ p:

Based on (33), the iteration for the power allocation , can be formulated as,

The Lagrangian multiplier λ, ν, are updated through the sub-gradient method, which are formulated as

where Kλ, Kν, Kϕ denote the step-size, and Kλ > 0, Kν > 0, Kϕ > 0. t denotes the iteration index. X + 0,X .

**B .computing resource allocation**

After obtaining P, the formulated problem with respect F reformulated by:

*max*

3

Notice that the constraints in (25b) and (25c) are convex, by calculating the second-order derivatives of Λ(X,F) w.r.t. the Lagrangian function is constructed to seek the optimal powers.

目标函数求导了

In order to prove the concavity of P5, the following research is taken.

The ﬁrst-order derivative of U0 c with respect to is,

The second-order derivative of is obtained further as,

it is obvious that The second-order derivative of U0 c with respect to ci is always less than 0. Therefore, U0 c is a concave function about ci, Hence, (25) is a convex optimization problem and can be solved using Karush-Kuhn-Tucker (KKT) conditions.

Joint Task Offloading Scheduling and Resource Allocation

where P∗ can be obtained through Algorithm 1

Algorithm 1: Distributed Robust Power Control Algorithm

Input

Initialize the log-domain power vector p ,computing resource allocation f and the Lagrangian multiplier vector λ u

repeat

Calculate

Update ˜ p and λ using (20) and (23), respectively.

Until synchronously converge to the optimal solutions ˜ p

Output:

Algorithm 2: Distributed computing resource Algorithm

Initialize the log-domain power vector p ,computing resource allocation f and the Lagrangian multiplier vector λ u

repeat

Calculate

Update ˜ p and λ using (20) and (23), respectively.

Until synchronously converge to the optimal solutions ˜ p

Output:

Based on the BCD Method.

SIMULATION AND PERFORMANCE EVALUATION

在这一节中，数值仿真被提出用来证明我们提出的算法是有效的

In this section, numerical simulations are presented to evaluate the performance of the proposed Algorithms 1 and 2.A mec-based vehicular network system which includes five clusters under a certain time slot is selected as our fundamental simulation scenario. The major system parameters are listed in Table III. It’s noted that the carrier frequency f and the bandwidth W are set as 2 GHz and 10 MHz respectively in the numerical simulations,We assume that both the vehicles and rsus use a single antenna for uplink transmission and reception, respectively.Unless stated otherwise, the parameter value of Ith is set to 10−6, the outage probability threshold .

假设车速在某个较小的时隙内为常数[85]。

除非特别说明，车辆速度与计算所需要的CPU周期数如下表所示task workloads.

为了进一步验证考虑了车辆移动性后所提出方案的性能，下图描述了不同伊普西路值下的是否完美信道信息对总效用的影响

We now evaluate the system utility performance against different number of users wishing to ofﬂoad their tasks, as shown in Fig. 4(a, b, c).

In terms of computing resources,

we choose the default task input size as du = 420KB (following [4], [10]),

为了让你们知道联合优化算法具有更好的有效性，我们找了四种方式做了对比

The purpose of this section is to show the convergence of our proposed algorithm and its performance is better than three benchmark schemes through some simulation results. The benchmark schemes are described as follow

“Without vehicle power control” (denoted as “Without-VPC”): The transmit power of the vehicles is set as average power during the offloading.

“Fixed trajectory”: the UAV ﬂies straight from the initial point with constant speed to the ﬁnal destination in the simulation model

这里可以改成不考虑车辆的移动性

固定计算资源分配为常数

“Non-robust”: Similar to [? ], the estimated location of the Eves are treated as its actual location. Therefore, it jointly optimizes the UAV trajectory, jamming power, and transmission power by using Algorithm 1 assuming ξ =0.

速度引起的不确定性忽略不计，

首先是不同情况下系统总效用的迭代收敛，从图中可以看出，鲁棒的联合优化性能优于其余三种情况

然后是在不同上传任务下四种方式的对比，可以看出

然后是在不同的CPU处理周期数的情况下的对比，可以看出，

The probability constraint of C2 can be transformed to the deterministic one according to the following inference

引言

随着汽车保有量的逐年攀升，城市交通拥堵日趋严重，交通事故日渐频发，同时也引发了诸多环境和能源问题。为了提升交通效率并保障交通安全，缓解相应的环境和能源危机，智能、灵活及可提供多样化服务的车联网应运而生。车联网是指用先进的传感器技术，并行计算机技术以及无线通信技术为基础，实现车与车

Joint Computation Task Offloading and Power Control for a MEC-Enabled Vehicular Network

System model of MEC-enable vehicular communications network

We consider a 高速公路路边拥有N个路边单元RSU，每个RSU服务周围M个汽车，每辆汽车以TDMA的方式接入周围的路边单元，在同一个时隙，向路边单元通信的车辆会对共用信道的车辆产生干扰，

Channel model

联合功率控制和移动边缘计算资源分配的高动态车联网

上传时间 .

the achievable rate [bits/s] of user i sending data to RSU

*.*

is the amount of input data necessary to transfer the program execution (including system settings, program codes, and input parameters)

处理时间

The transmission latency between RSU and cloud server is deﬁned as Tc, usually it is set to a ﬁx value.

**Reinforcement Learning for Joint Optimization of Communication and Computation in Vehicular Networks**

=5 denote the RSU computing capability in terms of CPU cycles/s.

denote the Cloud computing capability allocates to MEC in terms of CPU cycles/s

处理的效用

优化函数 *max*

3

4

优化问题的转化

*max*

2

3

4.

两个子问题

P1

2

4

P2

2

3 

拉格朗日乘子

P1

令导数为零



两边取对数得.

P2

目标函数求导了.

2

.

拉格朗日.

.

本文研究了一种车路云协同的车辆网络，联合优化了功率控制与计算资源分配，首先车辆用户上行链路传输信息向路边单元RSU，然后路边单元处理一部分，传到云处理一部分，路边单元与云端的信息传输使用的是有线传输。固定时间是0.01秒，本文只考虑了上行链路，使用TDMA的方式多址接入车辆。使得在每个时隙有多个汽车在向路边单元通信，

你相对的离中心较远，在顺义怀柔有一些数据要用北京城里的机器必须把数据也传输过来，传输比较费劲，在怀柔，也就是在边缘那能算的算的差不多了，或者算到中间的结果。减少了传输的时间，云计算与边缘计算原理上基本上是一样的，但是边缘不需要这么大，他只解决怀柔这儿附近的一些数据的计算，算出一个结果来再把数据传输到云端的计算机，如果这里到云的线很快，那么云计算也没关系的，你传过来就行了。但是这条传输起来更慢，数据量也很多

在这篇文章中，一种联合功率控制与移动边缘计算资源分配的方案被提出，

几年来，随着智能交通系统和自动驾驶技术的不断发展，移动边缘计算

开题报告

研究的目的及意义

随着我国汽车制造水平与经济实力的不断提升，国民汽车保有量持续攀升。根据中华人民共和国公安部公布的数据：截至目前，全国机动车保有量达4.08亿辆，其中汽车3.12亿辆；机动车驾驶人4.94亿人，其中汽车驾驶人4.56亿人。2022年上半年全国新注册登记机动车1657万辆，新领证驾驶人1103万人。据世界卫生组织 2018年 12月发布的《2018 年全球道路安全现状报告》[1]强调，每年死于道路交通事故的人数高达 135 万，造成的经济损失大约5180 亿美元，相当于各个国家生产总值的 1%-3%。高德地图在2021年度中国主要城市交通分析报告指出：同比2020年，2021年全国50个主要城市中有60%的城市路网高峰行程延时指数上升，24%的城市基本持平，16%的城市拥堵下降。因此得益于计算机技术的发展，智能驾驶辅助系统乃至于将来的完全自动驾驶逐渐成为当下的热点话题，除了在汽车上安装雷达感知周围信息之外，车辆通信也将发挥越来越大的作用，但是，车辆使用的蜂窝网络进行数据传输时受到带宽的限制，工业和信息化部关于印发《车联网（智能网联汽车）直连通信使用5905-5925MHz频段管理规定（暂行）》的通知公布了车联网（智能网联汽车）直连通信频率，因此如何在有限的带宽容量下支持更多的网联汽车接入网络成为当下学术界与工业界讨论的话题。

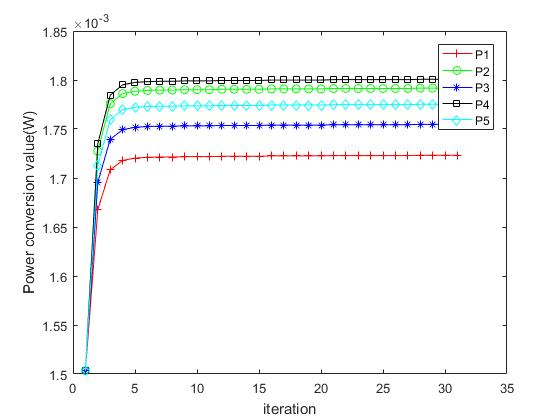
汽车自动驾驶过程中会产生大量的数据需要处理。车载CPU受限于体积与电源能量难以完成大量的数据计算，因此云计算与移动边缘计算将成为解决此问题的关键，云计算（cloud computing）是分布式计算的一种，指的是通过网络“云”将巨大的数据计算处理程序分解成无数个小程序，然后，通过多部服务器组成的系统进行处理和分析这些小程序得到结果并返回给用户。边缘计算与云计算原理上基本上是一样的，但是边缘计算可以更加灵活的部署在网络边缘的路边单元上，更加适合有着低延时与可靠传输的车联网的服务要求

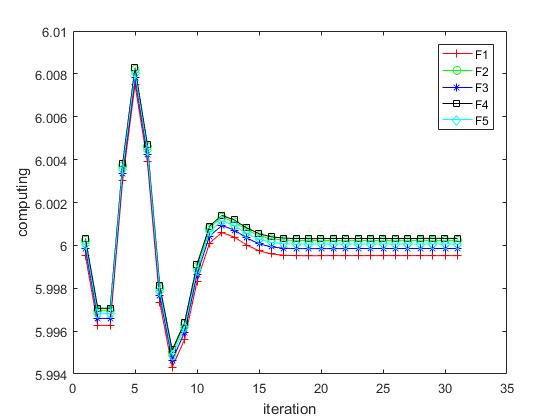
国内外研究现状及分析

Different from traditional mobile cloud computing (MCC), MEC migrates remote cloud computing resources to the edge of the network to reduce the end-to-end transmission delay of data and to relieve the computing and storage pressure of vehicles or intelligent roadside

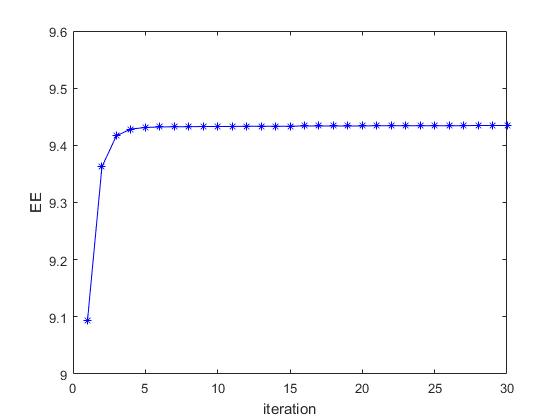
infrastructures.

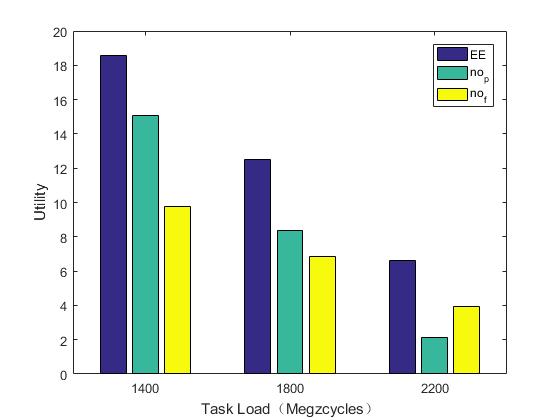
不同于传统的云计算，MEC将计算资源迁移到网络边缘以减小数据的端到端延时，并且缓解车辆或智能路边基础设施的计算和存储压力。





在图1中，每辆车向路边单元的发射功率与云分配给相应的路边单元的计算资源随着迭代次数的收敛情况





在不同的任务量下不同的处理方式得到的不同的效用最优值

