**Ⅱ MEC-enable vehicle network**

**A.系统模型**

In this paper,We consider A IoV edge computing network, consisting of 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。 numerous vehicle-to-RSU (V2I) cells underlay a macrocell. 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]. We denote the set of users and MEC servers in the mobile system as U = {1, 2,...,U} and S = {1, 2,...,S}, respectively. Some notations are given in Table II.

考虑了一条单向的高速公路，路边单元位于道路的一侧，MEC服务器部署于rsu旁，每个路边单元服务一个簇内的车辆，并将其未计算的数据通过有线的方式传输给远程的云端，根据 Cowan的 M3模型[86]的描述，相邻簇之间的距离服从截断指数分布，并假设车辆在每个时隙的速度满足常速度运动模型[85]由于簇内车辆与路边单元采用TDMA技术，每个时隙内只能有一个车与路边单元通信，簇内的其他车辆按照之前分配的时间顺序与路边单元通信，车辆将需要计算的任务卸载到路边单元后，移动边缘服务器首先进行一部分计算，然后将剩余的计算资源卸载到云端，基于地理特征将临近的车辆分为一个簇

**B. 通信模型**

Due to the fast mobility of vehicles, their CSIs are hard to be estimated precisely. 本文用大尺度和小尺度衰落模型去构建车辆信道增益的不确定性，the mobile V2I channel power gain of the effective links and interference links in mth time slot can be

expressed as a shared expression:

To improve the spectrum utilization and realize multi-user joint communication, V2I communications reuse the same uplink channel. In this case, the Signal-to-Interference-plus-Noise Ratio (SINR) from user u to RSU is given by,where pj denotes the transmit power of the vehicles，where σ2 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 du in the uplink can be calculated as, ， where W is the bandwidth of the reused channel. Therefore, the sum time of all D2D users can be formulated as

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

Communication delay is another signiﬁcant index that affects the performance of wireless networks. The packets to D2D-V receivers must be in the queue before they transmit at the speed of Ri. It is assumed that the process of a packet arriving at the ith D2D receiver is a Poisson process with parameter ςi, and the length of the data packet obeys the exponential distribution of parameter τi. Under the M/M/1 model [34], the relationship between the expected delay and transmission rate of the ith D2D pairs can be expressed as,

ε1,ε3 are the outage probability thresholds of SINR and delay constraint respectively, where ε1,ε2,ε3∈(0,1).

**C. 计算资源分配**

每个车在一个时刻内都有一个计算任务，定义为Tu，这个计算任务可以有两个参数表示，分别是和。Du代表车辆传输的执行程序系统参数，程序代码输入参数等必要的数据，cu代表执行这些程序需要的CPU工作量，

vehicle computation task

we consider that each vehicle has one computation task at a time. denoted as Tu , that is atomic and cannot be divided into subtasks. Each computation task Tu is characterized by a tuple of two parameters, du ,cu, in which du [bits] specifies the amount of input data necessary to transfer the program execution (including system settings, program codes, and input parameters) from the local device to the MEC server, and cu [cycles] specifies the workload, i.e., the amount of computation to accomplish the task. The values of du and cu can beobtained through carefully proﬁling of the task execution [7],[32]. Each task can be performed locally on the user device or offloaded to a MEC server. By offloading the computation task to the MEC server, the mobile user would save its energy for task execution; however, it would consume additional time and energy for sending the task input in the uplink.

The MEC server at each BS is able to provide computation ofﬂoading service to a vehicle at a time slot ，The computing resources are quantiﬁed by the fixed rate f拔 , 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 剩余的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 , The transmission latency between RSU and cloud server is deﬁned as Tc, usually it is set to a ﬁx value. Thus, the total latency for computing ofﬂoading can be written as

**效用函数**

Given the computing resource allocation fus ’s, the delay experienced by user u when offloading its task is given by . The transmission latency between RSU and cloud server is deﬁned as Tc, usually it is set to a ﬁx value.so the relative improvement in task completion time is characterized by ,where is the 阈值 of 时间，Therefore, we deﬁne the ofﬂoading utility of vehicle u as,

**优化问题的制定**

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,

该效用的含义是以较小的上传时间成本获得较大的执行时间效用，We now formulate the Joint Task Ofﬂoading and Resource Allocation (JTORA) 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 p denotes the network utility ，The constraints in the formulation above can be explained as follows: constraints

pi,max is the maximum transmit power of the transmit vehicle in 车辆网络中,

在 LTE-V2V 通信网络中，车辆的移动特性导致 V2V 链路的高可靠性难以满足。因此，在确保 CUE 用户通信质量的前提下，有必要提高 V2V 链路通信服务质量。本章引入了概率约束去确保 V2V 链路的可靠性得到满足，从而提高 V2V链路的系统性能。然而，由于信道增益是时变的，计算量大，在车载通信系统中实时捕获 SINR 是不现实的。利用车辆共享状态信息的信道估计技术，只能在很小的时间间隔内测量长期SINR。在这种情况下，由于 CSI反馈时间间隔很小，可以用长期 SINR 代替实时 SINR。

γi p denotes the average SINR of the ithD2D pairwhen a small CSI feedback time interval is used，Since the CU is the primary user served by mobile operators, its SINR should be guaranteed to be no less than the SINR threshold。

dmin is the SINR threshold for successful detecting the V2V communication。, pr{·} deﬁnes

the probability of the input,

Constraints (8c) and (8d) are used to guarantee the QoS requirements of VUEs and CUEs,

In this case, we introduce the outage probability constraint (8c) to guarantee the reliability of vehicular links.

Di,max is the upper delay bound of the ith D2D pair in the process of data transmission.

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.

6 states that the number of applications served by a particular edge cloud should be within its capacity

C2表示了通信时延与计算时延的小于一个设定的阈值

**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 three blocks and optimized alternatively.

Robust power control Optimization Algorithm

By ﬁxing P, 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 problem 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 it solvable. We can use the lower bound to approach the original function as follows.

24) can be used to compute the long term sum rate, R , for all the K D2D-V links in the simpliﬁed system,

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

It is obvious that the constraint (6) includes uncertainties and the objective function is an non-convex problem in (5). The objective function and constraints are difcult to deal with when determining the optimal solutions. In this paper, the approach of successive convex approximation is adopted to make the objective function solvable while ensuring QoS of CUE. For the uncertain channel gain, two different models 韩熙01 are analyzed and the uniform equivalent problem formulation is achieved. It is noted that, due to phase differences, speed

differences, topology changes, etc, V2CU links are more complex than V2V links. However, V2CU is different with CUE to BS links. The errormodel used asV2Vis not accurate enough. The channel gain model of V2CU links still belong to gain model of dynamic link. Numerous uncertainties in V2CU linksmake the description of errorsmore complicated, which is unlike V2V link. Two common forms are adopted to describe the uncertainty mentioned above, i.e. the statistical constraints and deterministic constraints.

Considering the fast fading, the general form the channel gain is described as,

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

In summary, we can obtain a deterministic optimization problem of robust power allocation by transforming the objective function, interference constraints, delay constraints, and packet

delivery rate constraints. It is expressed as,

P1

2

4

**B .computing resource allocation**

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

*max*

3

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

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，

云计算是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。

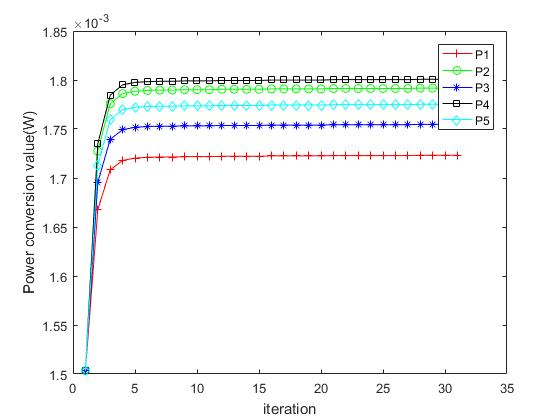
汽车自动驾驶过程中会产生大量的数据需要处理。车载CPU受限于体积与电源能量难以完成大量的数据计算，因此云计算与移动边缘计算将成为解决此问题的关键，云计算（cloud computing）是分布式计算的一种，指的是通过网络“云”将巨大的数据计算处理程序分解成无数个小程序，然后，通过多部服务器组成的系统进行处理和分析这些小程序得到结果并返回给用户。边缘计算与云计算原理上基本上是一样的，但是边缘计算可以更加灵活的部署在网络边缘的路边单元上，更加适合有着低延时与可靠传输的车联网的服务要求

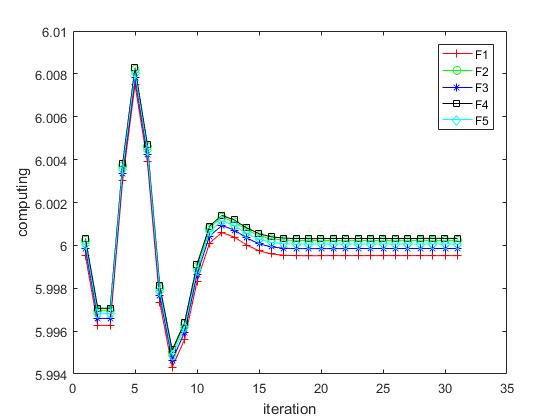
国内外研究现状及分析

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

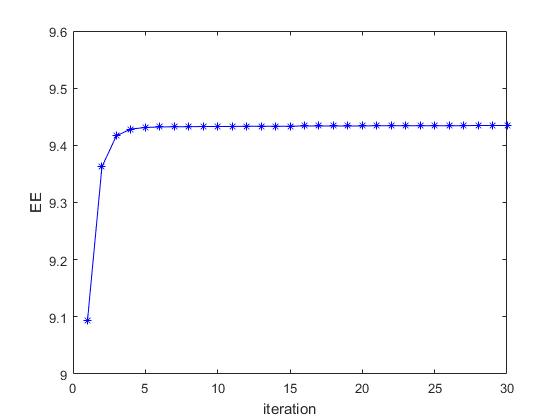
infrastructures.

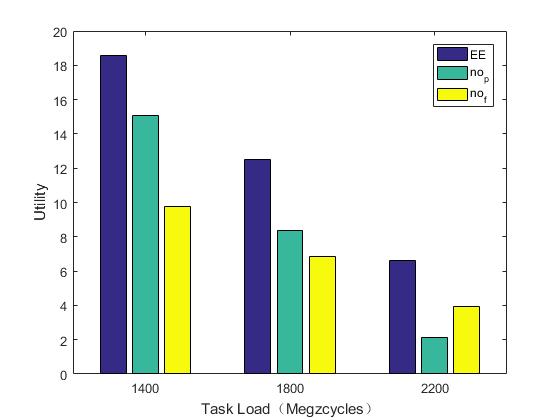
不同于传统的云计算，MEC将计算资源迁移到网络边缘以减小数据的端到端延时，并且缓解车辆或智能路边基础设施的计算和存储压力。





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