2021年2月5日 17:08

文献调研情况总结汇报

重点文献列表:

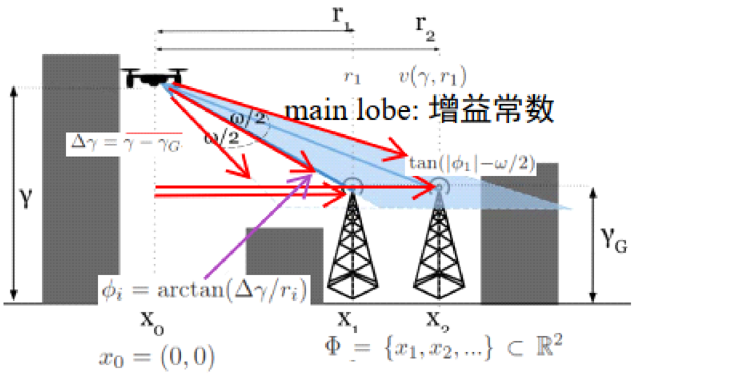
1.Galkin B, Kibilda J, DaSilva L A. **Backhaul for low-altitude UAVs in urban environments**[C]//2018 IEEE International Conference on Communications (ICC). IEEE, 2018: 1-6.2.
2.Kalantari E, Shakir M Z, Yanikomeroglu H, et al. **Backhaul-aware robust 3D drone placement in 5G+ wireless networks**[C]//2017 IEEE international conference on communications workshops (ICC workshops). IEEE, 2017: 109-114.
3.Kalantari E, Yanikomeroglu H, Yongacoglu A. **Wireless Networks with Cache-Enabled and Backhaul-Limited Aerial Base Stations**[J]. IEEE Transactions on Wireless Communications, 2020, 19(11): 7363-7376.
4.Zhang T, Wang Y, Liu Y, et al. **Cache-enabling UAV communications: Network deployment and resource allocation[J]. IEEE Transactions on Wireless Communications**, 2020, 19(11): 7470-7483.

所有文献可见于Github仓库 https://github.com/chengdusunny/UAVcomm

2021年2月5日 16:23

# 文献1要点概况

场景: 衡量一个UAV能够和地面基站取得连接的概率




已知一架UAV，不知道地面基站的具体位置，只知道地面基站的密度，如何衡量UAV成功把信息传送给地面基站的概率?

## 计算流程概况

### LoS表达式

$\boxed{\mathbb{P}_{LOS}(r_i)} =$ 关于ri的函数

$$\prod_{n=0}^{\max(0,d_i-1)} \left(1-\exp\left(-\frac{\left(\max(\gamma,\gamma_G)-\frac{(n+1/2)|\Delta\gamma|}{d_i}\right)^2}{2\kappa^2}\right)\right)$$

### 信噪比SINR表达式

根据LoS和NLoS不同

$$\mathrm{SINR}=\frac{pH_{t_1}\eta(\omega)\mu c\boxed{(r_1^2+\Delta\gamma^2)}^{\boxed{-\alpha_{t_1}/2}}}{\boxed{I_L+I_N}+\sigma^2} \qquad (3)$$

这是一个关于ri和倾角的函数

where $p$ is GS transmit power, $H_{t_1}$ is the random multipath fading component, $\alpha_{t_1}$ is the pathloss exponent, $t_1 \in \{\mathrm{L},\mathrm{N}\}$ is an indicator variable which denotes whether the UAV has LOS or NLOS to its serving GS, $\mu$ is the serving GS antenna gain defined in the next subsections, $c$ is the near-field pathloss, $\sigma^2$ is the noise power, and $I_L$ and $I_N$ are the aggregate LOS and NLOS interference, respectively.

### SINR大于门限值θ的条件概率

条件:水平距离r1,LoS

$\boxed{\mathbb{P}(\mathrm{SINR}\geq\theta|\boxed{R_1=r_1,t_1=\mathrm{L}})=}$ 关于ri的函数

$$\sum_{n=0}^{m_L-1}\frac{s_L^n}{n!}(-1)^n\cdot\sum_{i_L+i_N+i_\sigma=n}\frac{n!}{i_L!i_N!i_\sigma!}$$
$$\cdot\left(-(p\eta(\omega)c)^{-1}\sigma^2\right)^{i_\sigma}\exp\left(-(p\eta(\omega)c)^{-1}s_L\sigma^2\right)$$
$$\cdot\frac{d^{i_L}\mathcal{L}_{I_L}\boxed{((p\eta(\omega)c)^{-1}s_L)}}{ds_L^{i_L}}\frac{d^{i_N}\mathcal{L}_{I_N}((p\eta(\omega)c)^{-1}s_L)}{ds_L^{i_N}}, \qquad (7)$$

积分，得到UAV backhaul successfully的概率

$$\mathbb{P}(\mathrm{SINR} \geq \theta) = \int_0^\infty \Big( \boxed{\mathbb{P}(\mathrm{SINR} \geq \theta | R_1 = r_1, t_1 = \mathrm{L})} \mathbb{P}_{LOS}(r_1) + \mathbb{P}(\mathrm{SINR} \geq \theta | R_1 = r_1, t_1 = \mathrm{N})(1 - \mathbb{P}_{LOS}(r_1)) \Big) f_{R_1}(r_1) \mathrm{d}r_1. \tag{11}$$

The expected rate for the backhaul can be calculated using the backhaul probability as

$$\mathbb{E}[\mathcal{R}] = b \int_0^\infty \mathbb{P}(\mathrm{SINR} \geq 2^s - 1) \mathrm{d}s. \tag{12}$$

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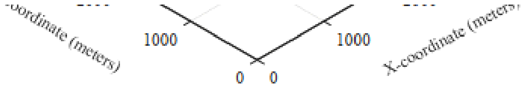
文献2要点概况

### A. *Network-Centric versus User-Centric* 如何确定用户权重？




network-centric尽可能服务更多的用户，不管其他权重相等

(b)

Fig. 2. User distribution and 3D drone-BS placement in a) network-centric and b) user-centric approaches. The drone-BS and its projection on XY-plane are shown in asterisk and red circles, respectively.

net-work-centric

The network may select the users based on the network-centric or the user-centric approach. In the network-centric approach, the network tries to serve as many users as possible, regardless of their rate requirements. As a result, the majority of the served users are the ones who need less data rates. In this approach, $\alpha_i$ in (16), is equal to 1 for all the users. In the

user-centric

user-centric approach, values of $\alpha_i$ vary with the users and they are determined based on the priority of users. A large number of existing and future applications may require differentiation among the users and applications; therefore, offering service only to the users with low rates would not be fair. There are different metrics such as the sum-rate, price differentiation, signal strength, and content demand to identify users priorities. These metrics are explained below:

*1) Sum-Rate:* One method of selecting users is to maximize the total sum-rate. In this way, by setting $\alpha_i$ equal to $r_i$, the users who require higher data rates are given higher priority to access the network. In this paper, we use this metric in the user-centric approach.

*2) Price Differentiation:* Users may be categorized based on how much they are willing to pay for their subscribed services, for instance, as platinum, gold, and silver users. The platinum users who pay higher, want to be connected to the network under almost every condition, even if their channel is poor or they need high amount of resources. By assigning a large value to $\alpha_i$ to such users, the service provider makes sure that they are served.

*3) Signal Strength:* The selection of the users can be based on their received signal strength, so the operator first serves the ones who have favorable channel conditions.

*4) Content Demand:* In content-aware systems, the users who need to access the network urgently based on their required content, are given higher priority.

The user distribution and the 3D placement of a drone-BS in a network-centric and a user-centric approach are shown

文献3要点总结

单基站+多UAV对地覆盖，优化覆盖率

(1)每个用户都被BS覆盖

*1) BS Association Constraints:* In our framework, each user should be served by only one BS. This yields the following constraint:

$$\sum_{j\in\mathcal{J}} \rho_{ij} = 1, \ \forall i \in \mathcal{I}, \tag{4}$$

i为定值

where $\rho_{ij} \in \{0, 1\}$ is a binary association indicator variable for user $i$ and BS $j$, and 1 indicates association.

(2)BS带宽限制

*2) Bandwidth Allocation Constraints:* The total amount of resources allocated by each BS to all the users cannot exceed the available bandwidth of that BS. Therefore,

$$\sum_{i\in\mathcal{I}} \rho_{ij}\beta_{ij} \le 1, \ \forall j \in \mathcal{J}, \tag{5}$$

j为定值

where $\beta_{ij} \in [0, 1]$ is the normalized resource of BS $j$ that is assigned to user $i$.

(3)BS回传信息率上限

*3) Data Rate Constraints:* The wide range of services requested by the users makes their demands fairly disparate. To ensure that data rate demands of the users are met, each user's rate must not be less than its target rate. Therefore,

$$\text{带宽B} \sum_{j\in\mathcal{J}} \boxed{\rho_{ij}B\beta_{ij}r_{ij}} \ge \boxed{\eta_i}, \ \forall i \in \mathcal{I}, \tag{6}$$

user i的需求

UAV j提供给user i的data-rate

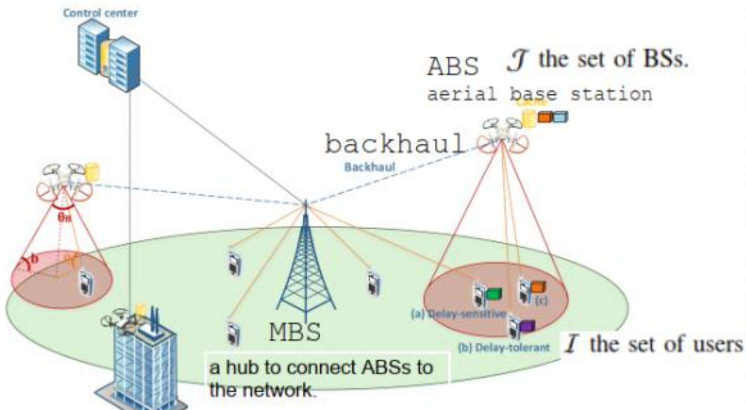
where $\eta_i$ is the data rate demanded by user $i$, $B$ is the total bandwidth of a BS, variable $r_{ij}$ is the received spectral efficiency of user $i$ when connected to BS $j$, and $\eta_i$ is the minimum required rate of user $i$. Assuming Shannon capacity is achieved, $r_{ij} = \log_2(1+\gamma_{ij})$, where $\gamma_{ij}$ is the SINR received by user $i$ from $j$th BS.

(4)携带内容

*4) User Type Constraints:* We assume that the total data in the network is $K$ files. We also consider a finite cache

Let us define the cache matrix $E^{J\times K} = [e_{jk}] = \{0, 1\}$ for ABSs, where $e_{jk} = 1$ denotes that ABS $j$ caches $k$th file and $e_{jk} = 0$ indicates the opposite. The user request matrix is also defined by $U^{I\times K} = [u_{ik}] = \{0, 1\}$, where $u_{ik} = 1$ means that user $i$ requests file $k$ and $u_{ik} = 0$ means the opposite. We assume that the central entity is aware of both matrices $E$ and $U$ and therefore, can control the caching strategy by obtaining the cache association matrix $\boxed{F^{I\times J} = [f_{ij}] = \{0, 1\}}$, where $f_{ij} = 1$ means that the content requested by user $i$ is cached in ABS $j$; otherwise, $f_{ij} = 0$. Here is an example to explain the caching strategy in more detail: Assume that there are 10 contents available in the network and each ABS can cache 20 percent of the total contents. Based on a certain placement strategy, ABS 1 decides to keep contents 2 and 4 in its local cache; therefore, $e_{12} = 1$ and $e_{14} = 1$. On the user side, if user 3 requests for content 4, $u_{34}$ becomes 1. As the central entity is aware of the whole matrix $E$ and $U$, it can obtain the entries of matrix $F$. In the aforementioned example, $f_{31} = 1$ as the requested content of user 3 is available in ABS 1.

Let us consider the case of delay-sensitive users only




术语:

backhaul 回传

BS: base station 基站

ABS: aerial base station

MBS: macro base station

创新: 把用户分为了高低两种优先级

Let us consider two groups of users in the system, namely delay-tolerant and delay-sensitive users. Such users can be

the latency issue, a delay-sensitive user should either associate with an MBS that has a wired backhaul to the core network or connect to an ABS that has the requested data in its local cache to avoid the need for a 2 hub connection from the ABS

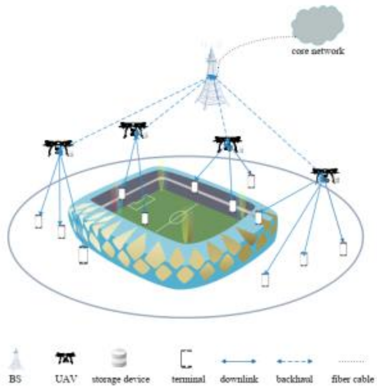



Fig. 1: Cache-enabling UAV-assisted cellular networks

entity is aware of the whole matrix $E$ and $U$, it can obtain the entries of matrix $F$. In the aforementioned example, $f_{31} = 1$ as the requested content of user 3 is available in ABS 1.

Let us consider the case of delay-sensitive users only associating with the MBS or ABSs if they have their requested data in their local cache, hence

j是否携带了i需要的1信息

$$\sum_{j \in \mathcal{J}} \boxed{f_{ij}} \rho_{ij} \geq \tau_i, \ \forall i \in \mathcal{I}, \tag{7}$$

delay-sensitive的用户必须有一个缓存了它需要的内容的UAV和它相连

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delay-sensitive的用户必须有一个缓存了它需要的内容的UAV和它相连

where $\tau_i \in \{0, 1\}$. $\tau_i = 1$ indicates that the user $i$ is delay-sensitive and $\tau_i = 0$ indicates the opposite. We consider $f_{ij} = 1$ for $j = 0$ as there is a wired connection from the MBS to the core network.

(5)LoS概率限制

*5) LoS Constraints for Association:* Adjustable altitudes in ABSs can increase the likelihood of establishing an LoS connection to ground users. A weaker channel implies higher transmit power and resource usage; therefore, to decrease the transmit power, we assume that user $i$ can be associated with ABS $j$ only if it has an LoS channel with a high probability with that ABS. Therefore,

对ij视距传输概率的要求

$$P(\mathrm{LoS})_{ij} \geq a\rho_{ij}, \ \forall i \in \mathcal{I}, \forall j \in \mathcal{J} \backslash 0, \tag{8}$$

where $a$ is a number close enough to one.

(6)backhaul capacity限制

*6) Backhaul Capacity Constraints:* The total data rate an ABS can support should not exceed its backhaul capacity. Note that by storing the content in the local cache of ABSs, we can alleviate the backhaul consumption. Accordingly,

当j没有i要求的内容时才向MBS请求

$$\sum_{i \in \mathcal{I}} \rho_{ij} B \beta_{ij} r_{ij} \boxed{(1 - f_{ij})} \leq C_j, \ \forall j \in \mathcal{J} \backslash 0, \tag{9}$$

j为定值

where $C_j$ is the backhaul capacity of ABS $j$.

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文献4要点总结
We formulate a joint optimization problem of UAV deployment, caching placement and user association for maximizing QoE of users, which is evaluated by mean opinion score (MOS).

要点1 contents被访问概率是不同的，起概率分布为zipf分布，所见文献都采用这周模型

Content popularity distribution

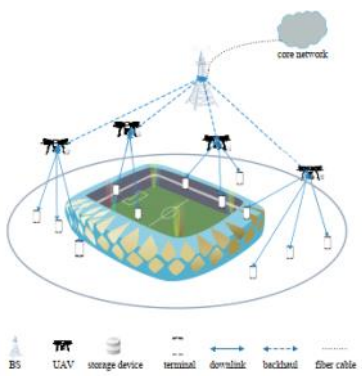
of $F$ contents follows a *Zipf*-like distribution. Without loss of generality, we rank these contents in a descending order according to their popularities. The popularity of the $i^{\text{th}}$ content is denoted as

$$\rho_i = \frac{1/i^{\gamma}}{\sum_{f=1}^{F} 1/f^{\gamma}}, \tag{35}$$

where the Zipf parameter $\gamma$ determines the skewness in the users' preference. The pathloss of LoS and NLoS link

以下内容来自文献3

content popularity follows a generalized Zipf law which states that the request rate $q(n)$ for the $n$-th most popular content is proportional to $\frac{1}{n^{\alpha}}$ for some $\alpha$ [33]. Typically, $\alpha$ is between




计算UAV到用户的时延 Transmission Delay

$$r_{m,n,k} = \frac{B}{\sum_{k=1}^{K} a_{m,k}} \log_2\left(1 + SINR_{m,n,k}\right)$$

$w_m = \sum_{k=1}^{K} a_{m,k}$,

$$b_{m,n} = \frac{B_h}{\sum_{k=1}^{K} a_{m,k}} \log_2\left(1 + SINR_{m,n}\right)$$

下行服务场景: 云端基站->UAV->用户

资源分配：联合优化问题

*C. Transmission Delay and MOS Model*

In our system model, the transmission delay is divided into two parts, i.e., the downlink radio transmission delay and the backhaul link transmission delay, as shown in Fig. 1. The downlink radio transmission delay from UAV $m$ to user $k$ is denoted as

s:size of content

$q_{k,f} = 1$ indicate that user $k$ requests the content $f$

$$D^a_{m,k} = \frac{\sum_{f=1}^{F} s q_{k,f}}{\boxed{r_{m,n,k}}} \tag{5}$$

Transmission rate from UAV $m$ in candidate location $n$ to user $k$

The backhaul link transmission delay from the MBS to UAV $m$ is denoted as

$u_{m,f} = 1$ indicates content $f$ is cached in UAV $m$,

$$D^b_{m,k} = \frac{\sum_{f=1}^{F} (1 - u_{m,f}) s q_{k,f}}{\boxed{b_{m,n}}} \tag{6}$$

Transmission rate from ground BS to UAV $m$ in candidate location $n$

If the content requested by user $k$ has been cached in UAV $m$, the backhaul link is no longer needed, that is, $D^b_{m,k} = 0$ when $u_{m,f} = 1$. The transmission delay from UAV $m$ to user $k$ is denoted as

$$D_{m,k} = \frac{\sum_{f=1}^{F} s q_{k,f}}{r_{m,n,k}} + \frac{\sum_{f=1}^{F} (1 - u_{m,f}) s q_{k,f}}{b_{m,n}}. \tag{7}$$

Let $w_m = \sum_{k=1}^{K} a_{m,k}$, we have

Indicator of whether user $k$ associated with UAV $m$

$$D_{m,k} = \frac{w_m \sum_{f=1}^{F} s q_{k,f}}{B \log_2\left(1 + SINR_{m,n,k}\right)} + \frac{w_m \sum_{f=1}^{F} (1 - u_{m,f}) s q_{k,f}}{B_h \log_2\left(1 + SINR_{m,n}\right)}. \tag{8}$$

Content access delay of user $k$ associated with UAV $m$

Inspired by the widely used QoE metric, mean opinion score (MOS) model is used as a measure of the users' QoE for the services like video streaming, content download, or web browsing. As one of the most popular application in wireless networks, we focus on video contents delivery in this paper. The value of MOS is depend on the transmission delay which is an important performance indicator of the mobile networks. The MOS model is denoted as [36]

QoE的衡量指标

UAV m是否部署在位置n

Each UAV has more than one candidate deployment locations to choose. Let $\boxed{x_{m,n} = 1}$ indicate that UAV $m$ is deployed in candidate location $n$, otherwise $x_{m,n} = 0$. Then the distance between UAV $m$ and user $k$, UAV $m$ and MBS with $x_{m,n} = 1$ are denoted as $d_{m,k} = \sqrt{\|\mathbf{w}_n - \mathbf{v}_k\|^2}$, $d_{m,0} = \sqrt{\|\mathbf{w}_n - \mathbf{v}_0\|^2}$ respectively, where $\mathbf{v}_k$ and $\mathbf{v}_0$ are the location of user $k$ and MBS respectively. Let $q_{k,f} = 1$ indicate that user $k$ requests the content $f$, otherwise $q_{k,f} = 0$. $\boxed{a_{m,k} = 1}$ indicates user $k$ is associated with UAV $m$, otherwise $a_{m,k} = 0$. One user can only be associated with one UAV, but one UAV can be associated with several users. $\boxed{u_{m,f} = 1}$ indicates content $f$ is cached in UAV $m$, otherwise $u_{m,f} = 0$. Each UAV can cache $H/s$ contents at most.

UAV m是否和user连接

UAV m是否储存了内容f

Inspired by the widely used QoE metric, mean opinion score (MOS) model is used as a measure of the users' QoE for the services like video streaming, content download, or web browsing. As one of the most popular application in wireless networks, we focus on video contents delivery in this paper. The value of MOS is depend on the transmission delay which is an important performance indicator of the mobile networks. The MOS model is denoted as [36]

QoS的衡量指标

$$MOS_{m,k} = C_1 \ln\left(\frac{1}{D_{m,k}}\right) + C_2, \tag{9}$$

$C_1$ and $C_2$ are both constants and $C_1 > 0$. It's obvious that the smaller the delay, the larger the MOS. From the results of our data we set $C_1$=1.120, $C_2$=4.6746 so that the value of $MOS_{m,k}$ is ranging from 1 to 5. The higher the score, the better the user's QoE will be.

问题描述

Let $Q_{m,k} = \ln(1/D_{m,k})$. In doing so, the formulated MOS maximization problem is transformed as follows,

$$\max_{x,a,u} \sum_{m=1}^{M}\sum_{k=1}^{K} a_{m,k} Q_{m,k} \tag{13}$$

$$\text{s.t. } a_{m,k} \in \{0,1\}, \forall m, \forall k, \tag{13a}$$

$$x_{m,n} \in \{0,1\}, \forall m, \forall n, \tag{13b}$$

$$u_{m,f} \in \{0,1\}, \forall m, \forall f, \tag{13c}$$

$$\sum_{m=1}^{M} a_{m,k} = 1, \forall k, \tag{13d}$$

每个user只能被一个UAV服务

$$\sum_{f=1}^{F} s u_{m,f} \le H, \forall m. \tag{13e}$$

Cache capacity of UAV

这里还有一个值得注意的地方: UAV和user进行匹配的时候，因为匹配还没有确定，所以只能用SINR代替SNR

and candidate locations. In the GS based initialization procedure, we calculate the SNR between UAV and users instead of SINR. Then the UAVs and candidate locations can build