



Resource Optimization for UAV-Enabled Multichannel Internet of Things

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Abstract. In this paper, the UAV as a relay forwards the information of multichannel IoT to the data center in the case of terrestrial channel fading. Throughput maximization for the multichannel IoT is studied, respectively, subject to the constraints of information-causality as well as total power and maximum rate of UAV. An iterative joint optimization algorithm is proposed to optimize the subcarrier, power and UAV trajectory alternatively, to achieve the optimal solution. The simulations show that the dynamic subcarrier allocation outperforms the fixed subcarrier allocation, and the joint optimization algorithm can improve the transmission performance of the UAV-enabled multichannel IoT effectively.

Keywords: UAV-enabled Multichannel IoT · Joint optimization · Transmit rate

1 Introduction

Internet of Things (IoT) has been widely used in transportation, agriculture, industry, logistics etc., which can realize the interconnections of all things based on the Internet, traditional telecommunication network and other information carriers [1]. However, relying on fixed communication facilities limits the mobility and deployment of the IoT. Recently, unmanned aerial vehicle (UAV) has been used as an ideal relay to assist the ground communications, due to the characteristics of agility, low cost and easy-to-deploy [2–4].

In [5], the optimal placement of an UAV in cooperative communications had been studied, which focused on the reliability by optimizing the UAV altitude. In [6], A system of multiple communication pairs had considered, which improved the cooperative performance by joint optimizing the position of UAV and resource allocation. In [7], Zeng et al. proposed an UAV-enabled mobile relaying system, whose throughput was maximized by optimizing the source/relay power allocation and the trajectory of the UAV by successive convex approximation (SCA). In [8], Jiang et al. considered an UAV-relayed system in the amplify-and-forward (AF) scenario, whose throughput was maximized by jointly optimizing the transmission power and UAV trajectory. As the mobility

of the UAV may generate great transmission performance difference, the fairness problem for UAV-assisted communication system should be considered. In [9, 10], the authors maximized the minimum user rate for an UAV-relayed system by joint power and UAV trajectory optimization.

Currently, there are fewer works on the UVA-enabled IoT, where the UAV can relay the information for multiple nodes. In this paper, An UAV-assisted multichannel IoT consisting of multiple nodes, one UAV relay and one data center is considered. Each node uses a single subcarrier to transmit its information to an mobile UAV, which then relays the information of all the nodes to and the data center.

2 System Model

We consider an UAV-assisted IoT constituting of K nodes and one data center. Assuming that the power for each node is constrained and the ground channel is in severe fading, the direct links from the nodes to the data center are ignored. Hence, the UAV is deployed to facilitate one-way communication from the node to the data center, which can forward the data previously received from the IoT node to the data center, as shown in Fig. 1.

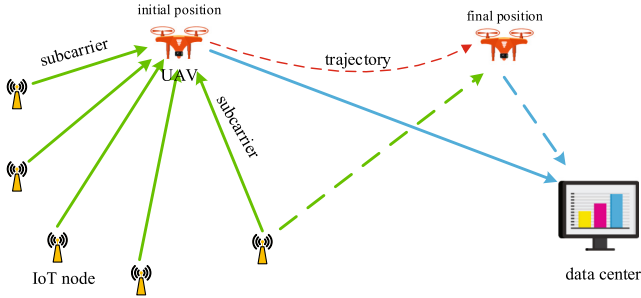


Fig. 1. A UAV-assisted IoT

Consider a Cartesian coordinate system, where the IoT nodes and the data center are located at $(x_1, y_1, 0), \dots, (x_K, y_K, 0)$ and $(L, 0, 0)$. Assume that the UAV is deployed at a stable height H , and there is no obstacle or building that makes the UAV rise or fall frequently. The flight trajectory of the UAV is denoted as $(x(t), y(t), H)$ for $0 \leq t \leq T$, where T is the flight time and $x(t), y(t)$ represent the plane coordinates. The initial position and the final position of the UAV are located at (x_o, y_o, H) and (x_F, y_F, H) , respectively. Hence, the minimum distance between the initial position and the final position of the UAV is $d_{min} = \sqrt{(x_F - x_o)^2 + (y_F - y_o)^2}$. Considering that the maximum speed of the UAV is V_{max} , let $V_{max} \geq d_{max}/T$ ensure that at least one feasible trajectory exists from the initial position to the final position. With the maximum UAV speed,

we have $\sqrt{(\nabla x(t))^2 + (\nabla y(t))^2} \leq V_{max}$ for $0 \leq t \leq T$, where $\nabla x(t)$ and $\nabla y(t)$ denote the derivatives of $x(t)$ and $y(t)$ in t , respectively.

Note that T is divided into U time slots, i.e., $T = U\delta_t$, where δ_t is so small that the position and speed of the UAV in each time slot is constant. The UAV trajectory in the u th slot can be described as $(x(u), y(u))$ for $1 \leq u \leq U$. Therefore, the constraints on the UAV trajectory and speed are given by

$$(x(1) - x_o)^2 + (y(1) - y_o)^2 \leq \varepsilon^2 \quad (1)$$

$$(x(u+1) - x(u))^2 + (y(u+1) - y(u))^2 \leq \varepsilon^2 \quad (2)$$

$$u = 1, 2, \dots, U - 1$$

$$(x_F - x(U))^2 + (y_F - y(U))^2 \leq \varepsilon^2 \quad (3)$$

where $\varepsilon = V_{max}\delta_t$ is the maximum displacement of UAV within one time slot.

In this paper, the transmit channel is divided into M narrow-band subchannels. $\omega = \{\omega_{m,k}(u), \forall k, m, u\}$, where $\omega_{m,k}(u) = \{0, 1\}$, represents the subcarrier assignment indicator in slot u . $\omega_{m,k}(u) = 1$ represents m th subcarrier is assigned to user k , otherwise, $\omega_{m,k}(u) = 0$. We assume that the communication channels from the IoT nodes to the relay and the relay to the data center are line-of-sight (LoS) links. Therefore, the Doppler effect can be ignored. The distances from each IoT node to the relay and the relay to the data center at slot u are given by $d_{sr,k} = \sqrt{H^2 + (x(u) - x_k)^2 + (y(u) - y_k)^2}$, $\forall k$ and $d_{rd} = \sqrt{H^2 + (L - x(u))^2 + y(u)^2}$, respectively. For simplicity, $q(u) = [x(u), y(u)]^T$, $z_d = [L, 0]^T$ and $z_k = [x_k, y_k]^T$ indicate the positions of UAV, data center and IoT node, respectively. In the free-space path loss model, the channel gain from the IoT nodes to the relay can be described as

$$h_{sr,k}(u) = \frac{\rho_k}{H^2 + \|q(u) - z(k)\|^2}, \quad \forall k, u \quad (4)$$

where ρ_k denotes the channel gain at unit distance $d_0 = 1$. We use $p_{s,k}^m(u)$ to denote the transmit power of k th node at slot u in subcarrier m . The maximum transmit rate from the nodes to the relay in slot u can be given by

$$R_s(u) = \sum_{k=1}^K \sum_{m=1}^M \omega_{m,k}(u) \log_2(1 + p_{s,k}^m(u) \gamma_{sr,k}(u)), \quad \forall u \quad (5)$$

where $\gamma_k = \rho_k/\sigma^2$ is the reference signal-to-noise ratio (SNR), and $\gamma_{sr,k}(u)$ is defined as

$$\gamma_{sr,k}(u) = \frac{\gamma_k}{H^2 + \|q(u) - z(u)\|^2}, \quad \forall k, u \quad (6)$$

Similarly, the channel gain from the relay to the data center can be described as

$$h_{rd}(u) = \frac{\rho_k}{H^2 + \|z_d - q(u)\|^2}, \quad \forall k, u \quad (7)$$

and the maximum transmit rate from the relay to the center is given by

$$R_r(u) = \sum_{k=1}^K \sum_{m=1}^M \omega_{m,k}(u) \log_2 (1 + p_{r,k}^m(u) \gamma_{rd,k}(u)), \quad \forall u \quad (8)$$

where $p_{r,k}^m(u)$ denotes the transmit power of the relay at slot u in subcarrier m , and $\gamma_{rd,k}(u) = \frac{\gamma_k}{H^2 + \|z_d - q(u)\|^2}$. Our goal is to maximize the total throughput from the IoT to the data center by jointly optimizing ω , $\mathbf{p} = \{p_{s,k}^m(u), p_{r,k}^m(u), \forall k, m, u\}$ and $\mathbf{q} = \{(x(u), y(u)), \forall u\}$ as follows

$$(P1): \max_{\mathbf{q}, \mathbf{p}, \omega} \sum_{u=2}^U R_r(u)$$

$$\text{s.t. } \sum_{i=2}^u R_r(i) \leq \sum_{i=1}^{u-1} R_s(i), \quad u = 2, 3, \dots, U \quad (9)$$

$$\sum_{k=1}^K \sum_{m=1}^M \sum_{u=1}^{U-1} \omega_{m,k}(u) p_{s,k}^m(u) \leq P_s \quad (10)$$

$$\sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) p_{r,k}^m(u) \leq P_r \quad (11)$$

$$p_{s,k}^m(u) \geq 0, \quad u = 1, 2, \dots, U-1 \quad (12)$$

$$p_{r,k}^m(u) \geq 0, \quad u = 2, 3, \dots, U \quad (13)$$

$$\sum_{k=1}^K \omega_{m,k}(u) = 1, \quad m = 1, 2, \dots, M \quad (14)$$

$$(x(1) - x_o)^2 + (y(1) - y_o)^2 \leq \varepsilon^2 \quad (15)$$

$$(x(u+1) - x(u))^2 + (y(u+1) - y(u))^2 \leq \varepsilon^2 \quad (16)$$

$$(x_F - x(U))^2 + (y_F - y(U))^2 \leq \varepsilon^2 \quad (17)$$

where (9) represents information causality constraint, i.e., the data capacity forwarded from the relay cannot exceed that received from the IoT nodes, P_s and P_r are total transmit power of IoT and relay, respectively, (14) represents one user occupies one subcarrier within one time slot.

3 Optimal Solution to P1

(P1) is non-convex and hard to solve directly. Therefore, we divide it into three suboptimization problems, including subcarrier allocation optimization, power optimization and UAV trajectory optimization. Then (P1) can be solved by an iterative algorithm for jointly optimizing subcarrier, power and trajectory. The subcarriers can be allocated to the nodes according to the channel gains, which are constant within one time slot. To guarantee transmission performance, one subcarrier is allocated to the node with the best channel gain on it, and the subcarrier cannot be occupied by the other users in this time slot.

3.1 Power Optimization

Assume the UAV trajectory is fixed, and the power optimization with fixed trajectory is considered. By ignoring the UAV's mobility constraints (15)–(17), (P1) can be converted into the power optimization problem with fixed UAV trajectory. However, it is still a non-convex optimization problem, which is difficult to solve directly. Hence, we introduce the slack variables $R_{r,k}(u)$, $u = 2, \dots, U$ to solve (P1), and (P1) is rewritten as follows

$$(P1.1): \max_{\mathbf{p}, \mathbf{w}, R_{r,k}(u)} \sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) R_{r,k}(u) \quad (18)$$

$$\text{s.t.} \sum_{k=1}^K \sum_{m=1}^M \sum_{i=2}^u \omega_{m,k}(i) R_{r,k}(i) \leq \sum_{i=1}^{u-1} R_s(i) \quad (19)$$

$$\sum_{m=1}^M \omega_{m,k}(u) R_{r,k}(u) \leq \sum_{m=1}^M \omega_{m,k}(u) \bar{R}_{r,k}(u) \quad (20)$$

$$\sum_{k=1}^K \sum_{m=1}^M \sum_{u=1}^{U-1} \omega_{m,k}(u) p_{s,k}^m(u) \leq P_s \quad (21)$$

$$\sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) p_{r,k}^m(u) \leq P_r \quad (22)$$

$$p_{s,k}^m(u) \geq 0, \quad u = 1, 2, \dots, U-1, \quad \forall k \quad (23)$$

$$p_{r,k}^m(u) \geq 0, \quad u = 2, 3, \dots, U, \quad \forall k \quad (24)$$

$$\sum_{k=1}^K \omega_{m,k}(u) = 1, \quad \forall m \quad (25)$$

where $\bar{R}_{r,k}(u) = \log_2(1 + p_{r,k}^m(u)\gamma_{rd,k}(u))$, and $R_s(u) = \sum_{k=1}^K \sum_{m=1}^M \omega_{m,k}(u) \bar{R}_{s,k}(u)$, where $\bar{R}_{s,k}(u) = \log_2(1 + p_{s,k}^m(u)\gamma_{sr,k}(u))$. The optimal power can be

achieved by the water-filling algorithm. The Slater's condition is satisfied for (P1.1), where the Lagrangian function is given by

$$L(\mathbf{p}, \mathbf{w}, \{\lambda_u\}, R_{r,k}(u)) = \sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) R_{r,k}(u) + \sum_{u=2}^U \lambda_u \left(\sum_{i=1}^{u-1} R_s(i) - \sum_{k=1}^K \sum_{m=1}^M \sum_{i=2}^u \omega_{m,k}(i) R_{r,k}(i) \right) \quad (26)$$

where $\lambda_u \geq 0$, $u = 2, 3, \dots, U$ are the Lagrange dual variables. By introducing $\theta_u = \sum_{i=u+1}^U \lambda_i$, $u = 1, 2, \dots, U-1$ and $\mu_u = 1 - \sum_{i=u}^U \lambda_i$, $u = 2, 3, \dots, U$, the function L can be rewritten as follows

$$L(\mathbf{p}, \mathbf{w}, \{\lambda_u\}, R_{r,k}(u)) = \sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \mu_u \omega_{m,k}(u) R_{r,k}(u) + \sum_{k=1}^K \sum_{m=1}^M \sum_{u=1}^{U-1} \theta_u \omega_{m,k}(u) \bar{R}_{s,k}(u) \quad (27)$$

The optimal solution can be obtained by solving the Lagrangian dual problem as follows

$$\min_{\lambda_u} f(\lambda_u) \quad (28)$$

$$\text{s.t.} \quad \lambda_u \geq 0, \forall u$$

where $f(\lambda_u) = \max_{\mathbf{p}, \mathbf{w}, R_{r,k}(u)} L(\mathbf{p}, \mathbf{w}, \lambda_u, R_{r,k}(u))$, s.t. (20)–(26)

The dual function $f(\lambda_u)$ can be obtained with fixed λ_u by maximizing L and then we minimize $f(\lambda_u)$ by finding the optimal dual solutions λ_u^* . Then the optimal power values can be obtained by substituting λ_u^* . By applying the Karush-Kuhn-Tucker (KKT) conditions and taking the derivatives of the objective function with respect to $p_{s,k}^m(u)$ and $p_{r,k}^m(u)$, respectively, the optimal power values of IoT nodes and UAV can be obtained as follows

$$p_{s,k}^{m*}(u) = \left[\frac{\theta_u}{\eta \ln 2} - \frac{1}{\gamma_{sr,k}(u)} \right]^+, \forall u, k \quad (29)$$

$$p_{r,k}^{m*}(u) = \left[\frac{\mu_u}{\nu \ln 2} - \frac{1}{\gamma_{rd,k}(u)} \right]^+, \forall u, k \quad (30)$$

where η and ν are the non-negative Lagrange multipliers associated with the constraints (21) and (22), respectively, and $[x]^+ = \max\{x, 0\}$. Then we can get $R_{r,k}^*(u) = \left[\log_2 \left(\frac{\mu_u}{\nu \ln 2} \gamma_{rd,k}(u) \right) \right]^+$.

3.2 Trajectory Optimization

Then the UAV trajectory will be optimized with the fixed power allocation. (P1) can be described as follows

$$(P1.2): \quad \max_{\mathbf{q}, \mathbf{w}, R_{r,k}(u)} \sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) R_{r,k}(u)$$

$$\text{s.t. } \sum_{k=1}^K \sum_{m=1}^M \sum_{i=2}^u \omega_{m,k}(i) R_{r,k}(i) \leq \sum_{i=1}^{u-1} R_s(i) \quad (31)$$

$$\sum_{m=1}^M \omega_{m,k}(u) R_{r,k}(u) \leq \sum_{m=1}^M \omega_{m,k}(u) \bar{R}_{r,k}(u) \quad (32)$$

$$(x(1) - x_o)^2 + (y(1) - y_o)^2 \leq \varepsilon^2 \quad (33)$$

$$(x(u+1) - x(u))^2 + (y(u+1) - y(u))^2 \leq \varepsilon^2 \quad (34)$$

$$(x_F - x(U))^2 + (y_F - y(U))^2 \leq \varepsilon^2 \quad (35)$$

where $R_s(u) = \sum_{k=1}^K \sum_{m=1}^M \log_2 \left(1 + \frac{\gamma_{s,k}(u)}{H^2 + \|\bar{q}(u) - z(u)\|^2} \right)$ and $\bar{R}_{r,k}(u) = \log_2 \left(1 + \frac{\gamma_{r,k}(u)}{H^2 + \|\bar{z}_d - \bar{q}(u)\|^2} \right)$, where $\gamma_{s,k}(u) \triangleq p_{s,k}^m(u) \gamma_k$ and $\gamma_{r,k}(u) \triangleq p_{r,k}^m(u) \gamma_k$.

(P1.2) is a non-convex optimization problem, which can be solved using the successive convex optimization method to optimize the trajectory increment of the UAV at each iteration. Assume $(x_j(u), y_j(u))$ is the UAV trajectory after the j th iteration, and $R_{sk,j}(u) \triangleq \log_2 \left(1 + \frac{\gamma_{s,k}(u)}{H^2 + (x_j(u) - x_k)^2 + (y_j(u) - y_k)^2} \right)$ and $R_{rk,j}(u) \triangleq \log_2 \left(1 + \frac{\gamma_{r,k}(u)}{H^2 + (L - x_j(u))^2 + y_j^2(u)} \right)$ are the corresponding transmission rates from the IoT nodes to the UAV and the UAV to the data center, respectively. Furthermore, $(\delta_j(u), \zeta_j(u))$ is denoted as the trajectory incremental from the j th to the $(j+1)$ th iteration. Then we can obtain [7].

$$\begin{aligned} R_{sk,j+1}(u) &\geq R_{sk,j+1}^{lb}(u) = R_{sk,j}(u) - a_{sk,j}(u) (\delta_j^2(u) + \zeta_j^2(u)) \\ &\quad - b_{sk,j}(u) \delta_j(u) - c_{sk,j}(u) \zeta_j(u), \forall k. \end{aligned} \quad (36)$$

$$\begin{aligned} R_{rk,j+1}(u) &\geq R_{rk,j+1}^{lb}(u) = R_{rk,j}(u) - a_{rk,j}(u) (\delta_j^2(u) + \zeta_j^2(u)) \\ &\quad - b_{rk,j}(u) \delta_j(u) - c_{rk,j}(u) \zeta_j(u), \forall k. \end{aligned} \quad (37)$$

where $\{a_{sk,j}(u), b_{sk,j}(u), c_{sk,j}(u)\}$ and $\{a_{rk,j}(u), b_{rk,j}(u), c_{rk,j}(u)\}$ are the coefficients of the links from the IoT nodes to the UAV and the UAV to the data center, respectively, which are describe as follows

$$\begin{cases} a_{sk,j}(u) = \frac{\gamma_{s,k}(u) \log_2 e}{d_{sr,j}^2(u) (\gamma_{s,k}(u) + d_{sr,j}^2(u))}, \\ b_{sk,j}(u) = 2(x_j(u) - x_k) a_{sk,j}(u), \forall u, k \\ c_{sk,j}(u) = 2(y_j(u) - y_k) a_{sk,j}(u) \end{cases} \quad (38)$$

and

$$\begin{cases} a_{rk,j}(u) = \frac{\gamma_{r,k}(u) \log_2 e}{d_{rd,j}^2(u)(\gamma_{r,k}(u) + d_{rd,j}^2(u))} \\ b_{rk,j}(u) = -2(L - x_j(u)) a_{rk,j}(u), \forall u, k \\ c_{rk,j}(u) = 2y_j(u) a_{rk,j}(u) \end{cases} \quad (39)$$

(36) and (37) represent the lower bounds of channel capacities with given trajectory increment. Then (P1.2) can be reformulated as follows

$$(P1.3): \quad \max_{\delta_j(u), \zeta_j(u), \mathbf{w}, R_{r,k}(u)} \sum_{k=1}^K \sum_{m=1}^M \sum_{u=2}^U \omega_{m,k}(u) R_{r,k}(u)$$

$$\text{s.t.} \quad \sum_{k=1}^K \sum_{m=1}^M \sum_{i=2}^u \omega_{m,k}(i) R_{r,k}(i) \leq \sum_{k=1}^K \sum_{m=1}^M \sum_{i=1}^{u-1} \omega_{m,k}(i) R_{sk,j+1}^{lb}(i) \quad (40)$$

$$\sum_{m=1}^M \omega_{m,k}(u) R_{r,k}(u) \leq \sum_{m=1}^M \omega_{m,k}(u) R_{rk,j+1}^{lb}(u) \quad (41)$$

$$(x_j(1) + \delta_j(1) - x_o)^2 + (y_j(1) + \zeta_j(1) - y_o)^2 \leq \varepsilon^2 \quad (42)$$

$$\begin{aligned} & (x_j(u+1) + \delta_j(u+1) - x_j(u) - \delta_j(u))^2 + \\ & (y_j(u+1) + \zeta_j(u+1) - y_j(u) - \zeta_j(u))^2 \leq \varepsilon^2, \forall u \end{aligned} \quad (43)$$

$$(x_F - x_j(U) - \delta_j(U))^2 + (y_F - y_j(U) - \zeta_j(U))^2 \leq \varepsilon^2 \quad (44)$$

which is a standard convex optimization problem and can be solved by the optimization tool CVX. Hence, the optimal solution to (P1.2) can be achieved by solving (P1.3).

3.3 Joint Optimization

An joint power, subcarrier and trajectory optimization algorithm is proposed to solve (P1) by alternatively optimizing (P1.1) and (P1.2). The joint optimization algorithm is described in Algorithm 1.

4 Numerical Results

We consider an IoT with $K = 8$ nodes randomly distributed in $2000 \text{ m} \times 500 \text{ m}$ regions, and $M = 8$ subcarriers with the bandwidth of 20 MHz and the

Algorithm 1. Joint power, subcarrier and trajectory optimization.

Require: the initial and final locations of the UAV, the power of IoT nodes and UAV, and the UAV trajectory;

- 1: **while** trajectory is not convergent or the maximum number of iterations has not been reached **do**
- 2: with given UAV trajectory, optimize the subcarrier allocation according to the channel gain;
- 3: with given power, optimize the UAV's trajectory by solving (P1.2);
- 4: with given UAV trajectory, optimize the power allocation by solving (P1.1);
- 5: **end while**

Ensure: subcarrier allocation, power of IoT nodes and UAV, and UAV trajectory.

carrier frequency of 4.9 GHz~5.04 GHz. The noise power spectrum density is -169 dBm/Hz. The altitude of the UAV is fixed to $H = 100$ m, which can avoid most obstacles. The maximum speed of the UAV is set as $V_{max} = 60$ m/s. The maximum average transmit power for each node and UAV is assumed to be $p_{s,k}^m(u) = p_{r,k}^m(u) = 20$ mW, respectively.

To verify the effect of mobile UAV on the IoT with the fixed UAV trajectory, two UAV trajectories are considered: (a) UAV is static at the location (1000, 0); (b) UAV flies from the initial location (750, 500) to the final location (1500, 500) with the maximum speed towards the data center. Then we consider two subcarrier allocation strategies: one is the subcarriers are dynamically allocated at each slot according to the channel gain, and the other is the subcarrier allocation is fixed in the first slot and remain unchanged until the end of the flight. The total transmit rate of IoT R_r versus the transmit time T is plotted in Fig. 2. It is observed that the transmit rate under the mobile UAV is higher than that

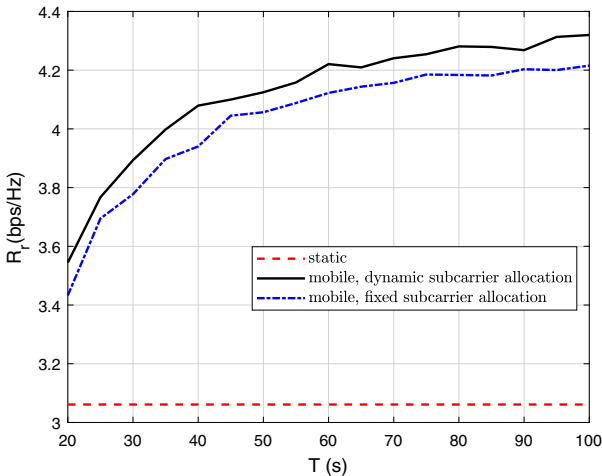


Fig. 2. Throughput in different subcarrier allocation and relay states.

in the static UAV. In addition, the transmission under the dynamic subcarrier allocation is higher than that under the fixed subcarrier allocation.

The UAV trajectory by the joint optimization algorithm is shown in Fig. 3. It is seen that the UAV first moves toward the IoT nodes and then closer to the data center instead of the direct flight. Such a trajectory can guarantee the UAV to receive enough data from the IoT.

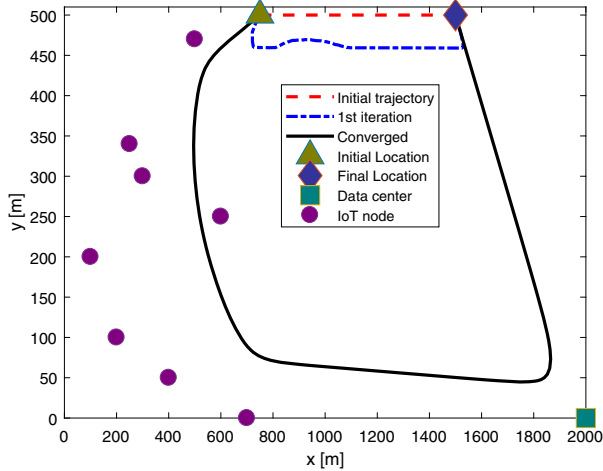


Fig. 3. UAV trajectory evolution by Algorithm 1; the circle, square, triangle, and diamond represent IoT node, data center, initial and final UAV locations, respectively.

5 Conclusions

In this paper, we propose resource optimization for an UVA-enable multichannel IoT, which seeks to maximize the throughput of the IoT by jointly optimizing subcarrier, power and UAV trajectory. The proposed optimization problems are divided into two sub-optimization problems, i.e., the power optimization under the fixed trajectory can be solved by the water filling algorithm, and the trajectory optimization under the fixed power can be achieved by the successive convex optimization. A joint optimization algorithm is given to obtain the optimal resource allocation. Numerical results show that the proposed resource optimization algorithm can improve the transmission performance of the UAV-enabled multichannel IoT effectively.

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