B. TECH. PROJECT REPORT

on

Outage Performance of Cache-Enabled 3D UAV-NOMA Terrestrial Network using DF Relaying

by

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1. INTRODUCTION

Unmanned aerial vehicles (UAVs) are already being employed in a variety of applications. Specifically, the use of UAVs in wireless communications promised a significant reduction in propagation loss owing to the air to ground LOS component connection. A slew of recent papers [1], [4] have attempted to propose stochastic UAV mobility models for UAV-based wireless network performance research. Furthermore, in [3], [4], a mixed-mobility (MM) model for 3D UAV movement was presented. Finally, based on the MM model, the performance of DF and AF 3D mobile relaying for HSTNs has been examined in [5], [6], and [7].

We used non-orthogonal multiple access (NOMA) for the UAV-aided model to acquire more accurate results in terms of spectrum efficiency, which indicated a superior strategy for 5G communications. NOMA is a technology that allows numerous users to serve on the same frequency while remaining multiplexed in the power domain.

Because of the increase in data traffic, there is a need for improved energy efficiency in 5G communications and beyond. The user requires improved spectral efficiency and data coverage [8], [10].

The wireless back-haul connections between the UAV and the source have a capacity constraint in UAV relayed communication. As a result, the system's performance will be lower than predicted, because system performance is dependent on data rates from UAV to user and source to UAV.

Caching the UAV relayed system mitigates such a difficulty. As a result, even without backhaul connectivity, the UAV may send data requested by the user if it is stored at the UAV. There are two primary caching schemes: the most popular content (MPC) caching scheme and the universal caching (UC) method [11]. Several papers [12], [13] have recently used wireless caching for relay networks. The fundamental MPC and UC caching techniques for AF relay networks were investigated in [10]. In contrast to these techniques, [13] investigated hybrid caching with optimization.

2. Motivation of the work:

- A relay sends data from the source to the destination. When there is a need for communication in emergency situations such as natural catastrophes, as well as traffic unloading in specific locations, the UAV relayed approach is a viable alternative.
  In such a case, relaying is a useful strategy for achieving reliable wireless communication.

- When compared to traditional ground relay, UAV mobile relay has the potential to deliver a significant performance boost due to the LOS link and flexibility in deployment.

- Researchers have fully explored NOMA approach because it exhibits high efficiency in spectrum analysis and broad connection in features such as physical layer security, cognitive radio network, and grouping schemes. These details encourage us to use

NOMA technology in UAVs.

- This technique will enable wireless systems to harvest energy from RF (radio frequency) transmissions while also doing IP (information processing).

- There are currently two schemes. The first is based on TS (time switching), in which time is shifted between IP and EH (energy harvesting) phases. The second is a PS-based one, in which a portion of the power received is utilised for energy harvesting and the remainder of the time is used for the IP phase.

- If the material requested by the terrestrial user is cached in UAV, there is no need for the primary source to be involved in sending the content, which typically occurs in two hops.

- By using caching, we may minimize transmission time in a single hop, so addressing latency and spectral efficiency difficulties, as well as quality of service concerns. It significantly minimizes propagation latency and bandwidth inefficiency.

3. Contribution:

3.1 System model:

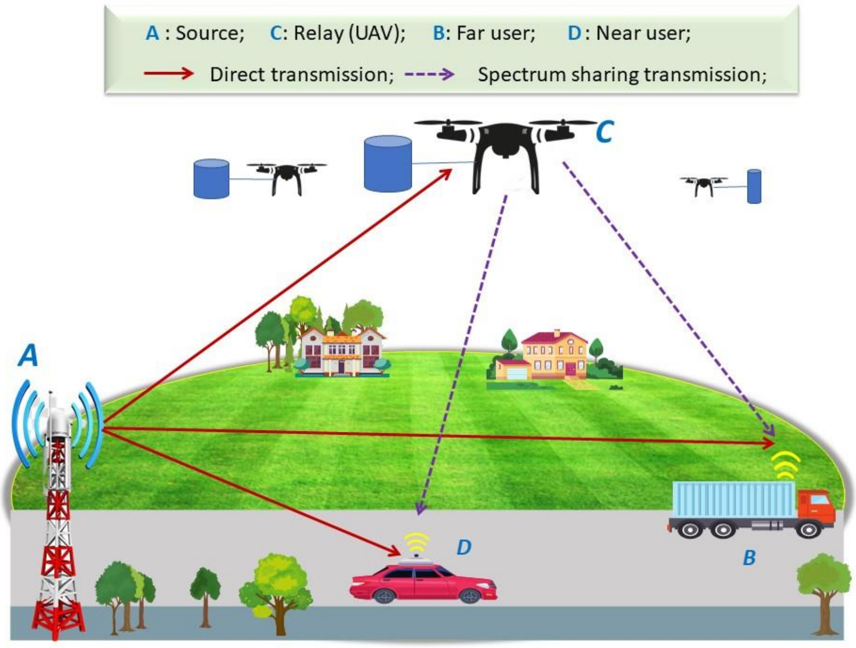

Fig. 1. OCNOMA system model.

As seen in Fig. 1, we investigate an OCNOMA system with a PT-PR pair coexisting with an ST-SR pair. Despite the fact that there is a direct primary (DP) relationship between the PT and the PR, the PT may seek assistance from the surrounding ST to reap the benefits of variety. In exchange, the ST is granted access to the primary's licensed spectrum for its own transmission to the SR. The PT is assumed to be powered by a constant power supply and sends its signal at a set transmit power.

Based on an overlay approach, the ST is permitted to access the licensed spectrum of the main in anticipation of cooperating the primary transmission between the PT and PR. ST functions as a cooperative relay and uses the NOMA approach to assist convey the PT's signal to PR while also sending its own signal to SR. As detailed in the sequel, we take a PS-based EH method and investigate the underlying SSC scheme employing DF relaying strategies for the examined OCNOMA system.

In the analytical framework, PT, PR, ST, and SR are represented by network nodes A, B, C, and D, respectively. We assume that all network nodes run in half-duplex mode and have single-antenna devices. Furthermore, the devices are equipped with less costly RF transceiver components, resulting in HIs. All channels are expected to follow block fading, which means they will remain static for the duration of the block but may change independently in the following block transmission.

The channel coefficients are susceptible to independent Nakagami - m fading [14] and are represented as h_{ab}, h_{ac}, h_{ad}, and h_{cd} for communication lines between PT and PR, PT and ST, PT and SR, ST and PR, and ST and SR, respectively. For i = {a, c} and j = {b, c, d} with i ≠ j, the channel gain $|h_{ij}|^2$ follows the Gamma distribution with average power Ω_{ij} and fading severity parameter m_{ij}, with i ≠ j. As a result, the pdf and cdf expressions of channel gain $|h_{ij}|^2$ may be provided by

$$f_{|h_{ij}|^2}(x) = \left(\frac{m_{ij}}{\Omega_{ij}}\right)^{m_{ij}} \frac{x^{m_{ij}-1}}{\Gamma(m_{ij})} \mathrm{e}^{-\frac{m_{ij}}{\Omega_{ij}}x}$$

$$F_{|h_{ij}|^2}(x) = \frac{1}{\Gamma(m_{ij})} \Upsilon\left(m_{ij}, \frac{m_{ij}}{\Omega_{ij}}x\right)$$

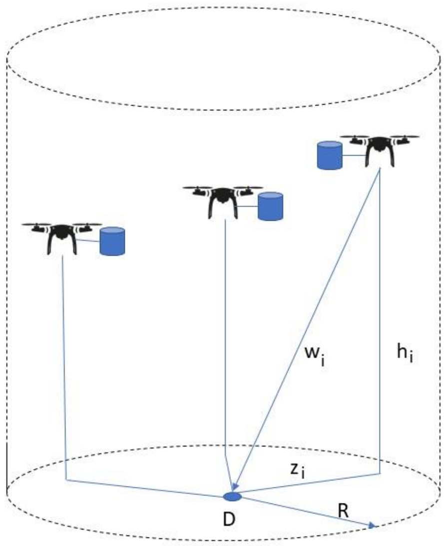

Fig. 2. HSTN system model with fully 3D mobile UAV relays.

The multi-parameter MM model [15],[16] which explains the 3D mobility of UAVs in a cylinder of height H and radius R, is considered. Based on the underlying parameters, the MM model may generate a wide range of mobility patterns for UAV relays. The UAV in this model makes vertical transitions using the RWP mobility model, with a random stay period at each waypoint. At time t, the weighted sum of a static pdf $f_{h_i}^{s_t}\left(\frac{x}{t}\right)$ and a mobility pdf $f_{h_i}^{m_0}\left(\frac{x}{t}\right)$ gives the pdf of instantaneous altitude of UAV hi(t).

$$f_{h_i}\left(\frac{x}{t}\right) = P_s f_{h_i}^{s_t}\left(\frac{x}{t}\right) + (1 - P_s) f_{h_i}^{m_0}\left(\frac{x}{t}\right)$$

Where P_s is defined as the probability of staying at waypoints, and the associated pdf equations are shown below.

$$f_{h_i}^{s_t}\left(\frac{x}{t}\right) = \frac{1}{H}$$

$$f_{h_i}^{m_0}\left(\frac{x}{t}\right) = -\frac{6x^2}{H^3} + \frac{6x}{H^2}$$

Furthermore, the instantaneous free-space pathloss between UAV Ui and nodes D may be represented as

$$w_{i_d}^{-\alpha}(t) = \left(h_i^2(t) + z_i^2(t)\right)^{-\alpha/2}$$

PT provides its information signal x_a during the first IP phase, in accordance with

$$E[|x_a|^2] = 1$$

As a result, the received signals at nodes B, C, and D, denoted by y_{ab}, y_{ac}, and y_{ad}, may be provided as

$$y_{ai} = h_{ai}\left(\sqrt{p_a} x_a + n_{t_a}\right) + n_{rai} + v_{ai}$$

where i = {b, c, d}, Pa signifies the transmit power at A, n_{ta} the distortion noise for transmit processing at node A, n_{rai} the distortion noise for receive processing at the i-th node, n_{ta} and n_{rai} the amount of impairments, and v_{ai} the AWGN variable

$$n_{ta} \sim \mathrm{C}N(0, \lambda^2 t_a p_a)$$

$$n_{rai} \sim CN(0, \lambda^2 raiP_a |h_{ai}|^2)$$

As a result, the consequent SNDR at i-th node, i = {b, c, d}, over the DP connection, may be expressed as

$$\Lambda ai^{Dp} = \frac{\Lambda ai}{\Lambda ai \lambda_{a_i}^2 + 1}$$

Where,

$$\lambda ai = \sqrt{\lambda_{rai}^2 + \lambda_{ta}^2 p_a}$$

$$\Lambda ai = |h_{ai}|^2 na$$

$$h_a = \frac{p_a}{\sigma^2}$$

During the second IP phase, ST employs a DF-based relaying technique and decodes the principal signal x_a. If ST is successful in decoding, it uses the NOMA principle to combine the decoded signal x_a with its own signal xc to form a superimposed signal z_c^{DF}. As a result, the signal sent by the ST node is given by

$$z_c^{DF} = \sqrt{\mu p_a} x_a + \sqrt{(1-\mu) p_a} x_c + n_{tC}$$

Following that, the obtained signals at PR and SR from ST may be supplied by y_{CD}^{DF} and y_{CB}^{DF}, which are represented as

$$y_{Cj}^{DF} = W_{id}^{-\frac{\alpha}{2}} \sqrt{\mu p_a} x_a h_{Cj} + w_{id}^{-\frac{\alpha}{2}} \sqrt{(1-\mu) p_a} x_c h_{Cj} + w_{id}^{-\frac{\alpha}{2}} n_{t_c} h_{Cj} + \ n_{rCj} \ + \ V_{Cj}$$

As a result, the SNDR expression at PR may be represented as

$$\Lambda_{CB}^{DF} = \frac{w_{id}^{-\alpha} \mu |h_{CB}|^2 n_a}{w_{id}^{-\alpha}(1-\mu) n_a |h_{CB}|^2 + w_{id}^{-\alpha} n_a |h_{CB}|^2 \lambda_{CB}^2 + 1}$$

Now, assuming that the PT's signal was successfully decoded at ST, the PR uses MRC to merge the PT's signal components received in the first IP phase (through DP transmission) and second IP phase (via relay transmission).

The SR performs SIC in accordance with the NOMA concept. To do this, the SR first decodes the PT's signal x_a, then eliminates x_a from y_{CD}^{DF} before decoding its own signal x_c. First, the SR decodes the PT signal while disregarding the ST signal as noise. Based on (12) and (13), the resulting SINDR expression at SR may be represented as

$$\Lambda_{cd \to x_a}^{DF} = \frac{w_{id}^{-\alpha} \mu |h_{CB}|^2 n_a}{w_{id}^{-\alpha}(1-\mu) n_a |h_{CB}|^2 + w_{id}^{-\alpha} n_a |h_{CB}|^2 \lambda_{CB}^2 + 1}$$

Remembering that the SR hearkens the PT's signal during the first IP phase, it may now use the MRC to decode x_a during the SIC process. SR may then decode x_a and delete it from the received NOMA signal y_{CD}. In the ip-SIC situation, the SINDR at SR is stated as

$$\Lambda_{CD}^{DF} = \frac{w_{id}^{-\alpha}(1 - \mu)|h_{CD}|^2 n_a}{w_{id}^{-\alpha}\mu|h_D|^2 n_a + w_{id}^{-\alpha} n_a |h_{CD}|^2 \lambda_{CD}^2 + 1}$$

We investigate the transmission of terrestrial connections from source A to UAV and UAV to ground users using UAV as a decode and forward (DF) relay. The channel models for communication linkages were then added, and the system model components were positioned in the cartesian coordinate system. For both NOMA users, we generated formulas for the SNR of the no-cached system.

4. FUTURE WORK

In this study, we consider a NOMA-UAV system with a wireless link from the base station to the UAV and the UAV to the users, where the UAV is mobile.
Taking 3D mobility into account, we will examine system outage performance, asymptotic analysis and produce analytical formulations for it.

We will do numerical simulations in MATLAB using the formulas. The resulting graphs will provide us with important insights into the influence of system settings on performance.

The theoretical analysis will be validated by the simulation findings.

We will broaden our scope of work. Using various caching techniques such as UC (universal content) caching and comparing them to the currently utilized strategy reveals the benefits and drawbacks of the schemes.

We will also use the Amplify and Forward (AF) approach instead of DF to evaluate the system model's performance.

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