Outage Probability Analysis of Sensor Nodes Served by Multi-antenna UAV-BS

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I. Introduction

An unmanned aerial vehicle (UAV) with a uniform linear array antenna (ULA) has been proposed to tackle the high outage probability due to low transmit power of sensor node (SN) and the existence of interfering SNs [1]. The purpose of this manuscript is to analytically compare the performance of ULA to that of selection diversity (SD) technique.

II. System and Channel Model

A UAV with M antennas is employed as a mobile data fusion center to receive signal from a desired SN, where the signal-to-interference plus noise power ratio (SINR) is expressed as follows

$$\gamma_0 = \frac{\Omega_0 \left|h_0\right|^2}{\sum_{k=1}^{K} \Omega_k \left|h_k\right|^2 + \sigma^2}, \quad (1)$$

where $\Omega_k = \frac{P_{\mathrm{T}}}{B}\frac{G_{\mathrm{T}} G_{\mathrm{R},k}}{L_k}$ is the received signal power of SN k with P_{T} and G_{T} denoting the transmit power and antenna gain of SNs, respectively, $G_{\mathrm{R},k}$ is the receive antenna gain for SN k at the UAV, B is the bandwidth, L_k and h_k are the path loss and the fading coefficient which follows non-centered chi-squared distribution between the UAV and SN k, respectively, and σ^2 is the variance of the additive white Gaussian noise (AWGN).

III. Outage Probability Analysis

A. Array Antenna

The closed form of outage probability (OP) of ULA equipped UAV-BS has been derived as follows [2]

$$P_{\mathrm{out}}(\gamma_{\mathrm{th}}) = \sum_{n=0}^{K_{tr}} \frac{\mathrm{e}^{-K_0} L_n^{(0)}(K_0)(1+K_0)^{n+1}}{(1+n)!{\Omega_0}^{n+1}} \gamma_{\mathrm{th}}^{n+1}$$
$$\times \sum_{k_1+\ldots+k_{K+1}=n+1} \binom{n+1}{k_1,\ldots,k_{K+1}} {\sigma^2}^{K+1} \prod_{j=1}^{K} \mathbb{E}[S_k^{k_j}]. \quad (2)$$

In this manuscript, Ω_0 is replaced by average received signal power $\overline{\Omega_0} = \frac{P_{\mathrm{T}}}{B}\frac{G_{\mathrm{T}} \overline{G_{\mathrm{R},k}}}{L_k}$ with

$$\overline{G_{\mathrm{R},k}} = \frac{\int_0^{\tan^{-1}\frac{R}{H_{\mathrm{UAV}}}} \int_{W_{\mathrm{L}}}^{W_{\mathrm{U}}} G_{\mathrm{R},k} \delta\phi\delta\theta}{(W_{\mathrm{U}} - W_{\mathrm{L}}) \tan^{-1}\frac{R}{H_{\mathrm{UAV}}}}, \quad (3)$$

where W_{L} and W_{U} are the minimum and maximum angle of the ULA beam, respectively, R and H_{UAV} are the area radius and the altitude of the UAV-BS, respectively, and $\tan^{-1}\frac{R}{H_{\mathrm{UAV}}}$ is the possible range of elevation angle θ.

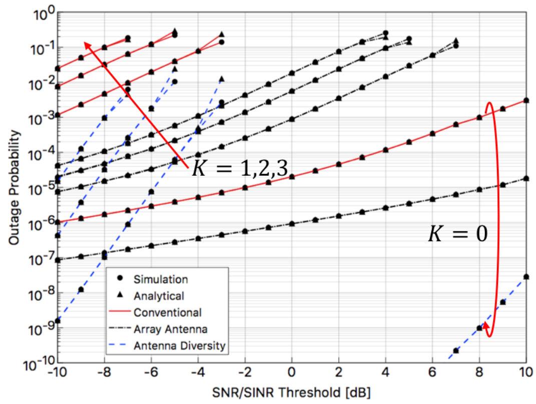

Fig. 1: OP vs SNR/SINR Threshold

B. Antenna Diversity

When SINR-based SD technique is adopted, the SINR is given by

$$\gamma_{\mathrm{SD}} = \max_{1\leq m\leq M} \gamma_0^m, \quad (4)$$

where SINR γ_0^m of the desired SN is assumed to be independent at each UAV-BS antenna branch $m \in [1, M]$. The OP is given by

$$P_{\mathrm{out,SD}}(\gamma_{\mathrm{th}}) = \prod_{m=1}^{M} P_{\mathrm{out},m}(\gamma_{\mathrm{th}}), \quad (5)$$

where $P_{\mathrm{out},m}(\gamma_{\mathrm{th}})$ is the OP of desired SN at UAV-BS antenna branch m.

IV. Result and Conclusion

Fig. 1 shows the analytical and the simulation values match perfectly, which indicates the derived outage probability expression is valid. Both ULA and SD can provide lower OP than conventional method with a single omni antenna. Exploiting the antenna diversity shows superior performance compared to the array antenna when no interfering SN exists but inferior when interfering SN exists. This is because the main beam of ULA can be set toward the desired SN by exploiting the dynamic deployment of UAV-BS.

Acknowledgment This work was supported by JSPS KAKENHI Grant Number JP18K04127.

References [1] H. Lumbantoruan, et. al., "Array Antenna for Power Saving of Sensor Nodes in UAV-BS enabled WSN, " *ICNC* 2019. [2] H. Lumbantoruan, et. al., "OP Analysis of Sensor Nodes Served by an ULA Equipped UAV-BS," *IEICE General Conf.* 2019.

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