A New Transmission Strategy for Data Fusion Using High-altitude Platforms

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***Abstract*—This paper introduces a data fusion strategy for environmental and industrial monitoring via wireless sensor networks (WSNs). We propose a new waveform that reduces the overall complexity and the number of required physical channels. By utilizing the proposed waveform, all sensors within the wide area transmit a signal that contains the local information source. We demonstrate that the proposed transmission strategy enables the fusion center, a high-altitude platform, to estimate information from any location within the coverage area.**

***Index Terms*—sensor network, high-altitude platform**

I. Introduction

Wireless sensor networks can relay local sensor measurements to the fusion center, creating a comprehensive map of the information source [1]. However, addressing the network routing problem with limited resources is challenging, and achieving ultra-low latency in data collection is nearly impossible. In this paper, we introduce a method that collects the information source leveraging spatial correlation. Sensors transmit their local measurements using predefined waveforms. Consequently, the high-altitude platform (HAP) can estimate information from any location through simple post-processing [2]. While all sensors use the same time-frequency resources to minimize overall consumption, the HAP discerns local information by utilizing spatial correlation.

II. Real-time Wide-area Information Mapping

We assume that L users are distributed over the $2R \times 2R$ area. The location of ℓ-th user is denoted as (x_ℓ, y_ℓ, z_ℓ). The HAP is located at $(0, 0, H)$. The correlated information source is represented as $i(x, y; t)$, $i \sim N(0, \rho_{\mathrm{i}}^2)$, which is the information source at the location of (x, y) and time t. The receiver antenna at the HAP is equipped with an antenna array with the size of $M \times N$, and we assume that the users utilize the time-frequency resource block with the size of $S \times F$.

For a block fading multipath uplink channel, users can locally calculate the following coefficients for every $s \in [0, S-1]$ and $f \in [0, F-1]$:

$$\alpha_{\ell,s,f} = e^{j2\pi\left[2f\nu_\Delta \Delta_\ell - \frac{d}{\lambda}\left(M p_{\mathrm{m}}^{s,f} \cos\theta_\ell^y + N q_{\mathrm{m}}^{s,f} \cos\theta_\ell^x\right)\right]} \alpha_{\ell,0,0}, \quad (1)$$

where $p_{\mathrm{m}}^{s,f} = p_{\mathrm{map}}(s, f)$ and $q_{\mathrm{m}}^{s,f} = q_{\mathrm{map}}(s, f)$ are the predefined bijective mapping function, $\Delta_\ell = \frac{d_\ell - d_{\min}}{c}$, and ν_Δ is the subcarrier spacing. The symbol $d_{\min}$ denotes the distance between the HAP and the user closest to the HAP. The symbols $\cos\theta_\ell^x$ and $\cos\theta_\ell^y$ can be calculated as $\cos\theta_\ell^x = -\frac{x_\ell}{d_\ell}$ and $\cos\theta_\ell^y = -\frac{y_\ell}{d_\ell}$. The symbol $\alpha_{\ell,0,0}$ can be any unit phaser, so we set to $\alpha_{\ell,0,0} = 1$. By utilizing this transmission waveform, the receiver at the HAP can regenerate the map of the information source through inverse discrete Fourier transform (IDFT).

This work was supported by Institute of Information & communications Technology Planning & Evaluation (2022-0-00704).

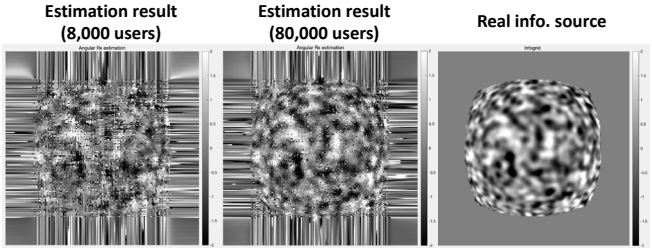

Fig. 1. Generation of the information map for different user numbers.

III. Results

Simulations were conducted over a 40 km$\times 40$ km grid, placing the HAP at a 20 km altitude. We estimate that $8,000$ and $80,000$ users span this region, modeled by the Poisson Point Process. As depicted in Fig. 1, the HAP accurately recreates the original information source image.

IV. Conclusion

We proposed novel transmission strategy that uses HAPs to generate the correlated information sources on the ground. Simulation results indicate that, despite massive and asynchronous transmissions from ground users, the HAP can generate an information map using a simple IDFT process. For future research, we aim to determine the performance boundary of our approach and compare it with conventional wireless networks with orthogonal sensor access.

References

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