



Signal processing design for enabling massive wireless connectivity

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Abstract

To realize multiuser MIMO-OFDM capable of simultaneous connections with massive numbers of wireless devices (Fig. 1), a key challenge is the carrier-frequency offsets (CFOs) among terminals. CFOs break the orthogonality of OFDM subcarriers, degrade channel estimation, and hinder reliable communication. To overcome this, we propose a Bayesian-inference-based receiver that jointly estimates the channel, CFOs, and data symbols. The method embeds prior knowledge of the sparse time-domain channel and the statistical behavior of CFO-induced phase rotations, and achieves stable, accurate estimation even with short pilot sequences through Bayesian message passing.

Background & Results

Conventional receivers perform CFO estimation, channel estimation, and data detection in a sequential manner, causing severe performance degradation due to error propagation under multiuser conditions with short pilot sequences. This study integrates these tasks into a unified Bayesian inference framework and demonstrates a receiver architecture that achieves high estimation accuracy and stable communication quality even with limited pilot resources.

In a cyber-physical society where the digital and physical worlds are tightly interconnected, vast amounts of data must be collected from an enormous number of IoT devices via wireless links, and CFO compensation is one of the major obstacles to realizing such large-scale uplink access. The proposed method provides a key technology for enabling massive simultaneous connections with practical pilot overhead, and it is also expected to serve as an estimation foundation for device synchronization and device identification, which will be indispensable in future cell-free and cooperative distributed networks.

Significance of the research and Future perspective

In future societies envisioned by concepts such as Society 5.0 and 6G, it will be essential to aggregate real-world information from a massive number of devices to the cloud and process it with high reliability and low latency (Fig. 2). As a core uplink technology for such systems, multiuser MIMO-OFDM has attracted significant attention. However, since each device in practice uses its own oscillator, carrier-frequency offsets (CFOs) inevitably arise among terminals. These CFOs destroy the orthogonality of OFDM subcarriers, degrade channel-estimation accuracy, and ultimately lead to deterioration in communication quality.

In this study, the received signal in multiuser MIMO-OFDM is formulated as a bilinear model with two unknowns: the time-domain channel and the CFO-induced phase rotations. A Bayesian-inference-based receiver is then designed. Channel sparsity in the delay domain is captured by a Bernoulli-Gaussian prior, while CFO statistics are modeled using a Gaussian mixture consistent with standard-specified ranges, enabling efficient estimation even with short pilots. An iterative refinement scheme further improves ac-

curacy by feeding back detected data symbols. As shown in Fig. 3, the proposed method substantially outperforms conventional techniques and approaches the performance of a "genie-aided" receiver with perfectly known channels and CFOs.

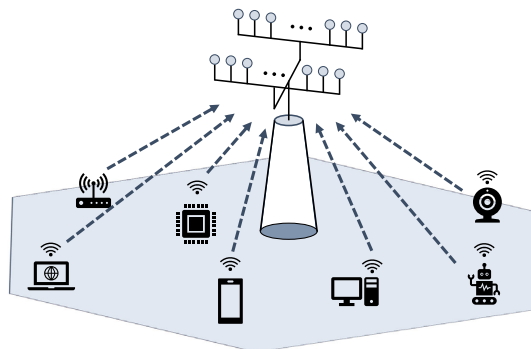


Fig. 1 Illustration of a Multi-User MIMO-OFDM System

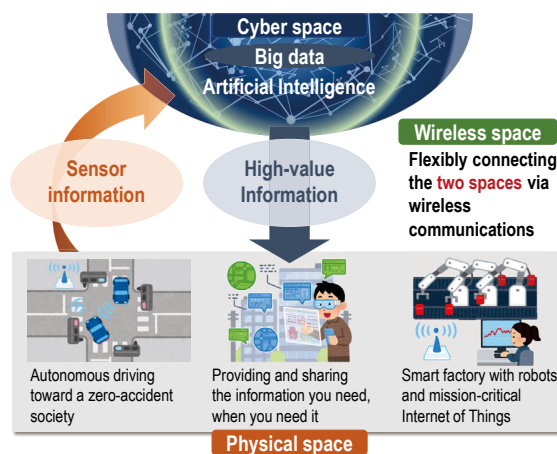


Fig. 2 Cyber-Physical System (CPS)

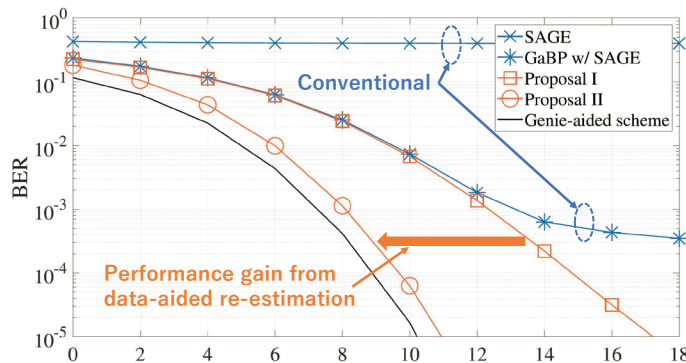


Fig. 3 Performance Evaluation through Computer Simulations

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Keyword

Takahashi, Takumi; Imori, Hiroki; Ishibashi, Koji et al. Bayesian bilinear inference for joint channel tracking and data detection in millimeter-wave MIMO systems. *IEEE Transactions on Wireless Communications*. 2024, 23(9), 11136-11153. doi: 10.1109/TWC.2024.3379122
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wireless communications, signal processing, Bayesian statistics, information theory