A Novel Decoding Algorithm of Superposition Modulation for Cooperative IoT System

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***Abstract* – In this paper, we propose a novel decoding strategy for superposition modulation (SM) for cooperative IoT system. Unlike the conventional method where the SIC (successive interference cancellation) decoding is applied, whose performance degrades when the decoder fails to detect the main signal, we propose a novel decoding algorithm which derive the LLR (log likelihood ratio) directly from the received signal. The new decoding scheme performs well even when the main signal detection fails and outperforms conventional SIC based decoding method by more than 2 dB in the fading environment.**

1. INTRODUCTION

최근 IoT 통신 시스템의 신뢰성을 높이기 위한 수많은 연구들이 진행되었다. 전력과 비용의 제한으로 인해 IoT 기기에 다이버시티 효과를 얻기 위한 다중안테나 기술을 적용하기에 어려움이 따른다. 따라서 협력통신이 공간 다이버시티 효과를 얻기 위한 좋은 대안이 된다. 본 논문에서는 AF(Amplify and Forward), DF(Decode and Forward)와 CF(Compress and Forward) 협력통신 방식 중 DF 방식에 초점을 맞춘다.

데이터 전송률을 확보하고 송신 전력소비량을 줄이기 위해서 재전송 단계에서 중계 노드로부터 소스 노드와 자신의 패킷을 SM으로 전송하는 방식이 소개되었다.[5]-[6] 수신단에서는 SIC 알고리즘을 적용하여 소스 노드와 중계 노드의 정보를 복호화하는 방식을 적용했다.

종래 SM 방식의 문제점은 SIC 알고리즘이 power ratio가 큰 신호의 복호화 여부에 따라 BER 성능을 저하시킨다. 본 논문에서는 Error propagation 효과를 개선하기 위해서 수신한 신호로부터 각 노드의 LLR 정보를 직접적으로 추출하는 복호화 방식을 제안한다.

1. SYSTEM MODEL
2. PROPOSED DECODING ALGORITHM
3. SIMULATION RESULT

BER Performance Comparison with same

 

 



//run more samples

1. CONCLUSIONS
2. REFERENCE
3. Spectral, energy and economic efficiency of relay-aided cellular networks(2013, journal) - cooperative network의 SE, economic efficiency를 연구함.
4. Cooperative diversity in wireless networks(2004, journal) - Cooperative network에서 relay가 AF 혹은 DF 방식을 취함.

\*AF cooperative system에서 relay는 단순히 signal을 증폭시켜서 재전송하기만함. 성능개선에 도움을 주기보다 전송지연만 발생시킬 수 있음. AF와 달리, DF는 수신한 신호를 decoding하여 재전송함. 이는 error detection을 forward할 수 있고, signal processing capacity를 필요로 함.

1. Threshold selection for SNR-based selective digital relaying in cooperative wireless networks(2008, journal) - cooperative system에서 SNR threshold를 이용하여 BER을 낮추는 방식을 고안함. (이후 다양한 cooperative network에 관한 논문이 진행됨.)
2. Optimum thresholdselection relaying for decode-and-forward cooperation protocol(2006, conference) - optimal threshold selection에 관한 논문

\*FDF(Fixed DF) : relay just DF its received msg

\*ADF(Adaptive DF, aka SDF) : relay only DF relay가 decoding success일 경우만

1. Optimum threshold for SNR-based selective digital relaying in cooperative wireless networks(2007, conference) - optimal SNR threshold를 이용해서 SDF BER을 최소화시키는 방법을 연구하는 논문
2. Performance analysis of SNRbased hybrid decode-and-forward cooperative diversity networks over Rayleigh fading channels(2010, conference) - Rayleigh fading channel에서 HADF 연구 논문

\*HDAF : relay에서 decoding에 실패해도 AF

1. Performance analysis of hybrid decodeamplify-forward incremental relaying cooperative diversity protocol using SNR-based relay selection(2013, journal) - SNR을 기준으로 multi relay system에서 incremental HDAF relay selection을 연구하는 논문.
2. Performance Analysis of SNR-Based Incremental Hybrid Decode-Amplify-Forward Cooperative Relaying Protocol(2015, journal) - SNR\_sd가 threshold를 만족하면 src Tx. SNR\_sr이 threshold를 만족하면 Relay DF, 아니면 AF. Plus, power constraint를 정함. IoT 관점에서 DF는 phase 낭비 ⇨ superposition을 적용하자. 이 때, 적용할 수 있는 better decoding scheme은?
3. Power-Domain Non-Orthogonal Multiple Access (NOMA) in 5G Systems: Potentials and Challenges(2017, journal)

NOMA in CoMP는 Downlink NOMA에서 STBC 방식을 적용함. Superposition을 적용한 Uplink는 아님.

NOMA scheme으로 적용할 수 있는 아이디어들을 정리한 논문

Uplink NOMA는 spatial modulation을 말하는데, superposition CoMP를 적용하는게 말이 되나? >> multi destination(BS)로 전송하는 scheme인데, BER 성능을 개선하는 scheme. BS간 광통신으로 error free combining이 가능함.

Edge cell user의 efficiency를 증가시키자는게 CoMP의 기본 아이디어

1. Cooperative Transmit Diversity Based on Superposition Modulation(2005, journal)

Incremental superposition modulation을 취할 때, 성능 개선을 conventional superposition에 비교함.

1. Capacity Analysis of Cooperative Relaying Systems Using Non-Orthogonal Multiple Access(2015, journal)

Rayleigh fading 채널에서 achievable average rate을 제시하고, NOMA에서 suboptimal power allocation을 제시함.

1. Spectral and Energy-Efficient Wireless Powered IoT Networks: NOMA or TDMA?(2018, journal)

IoT network에서 circuit의 energy consumption을 비교한 결과, TDMA 방식의 WPCN이 energy efficiency나 spectral efficiency 측면에서 유리함.

1. ~~A Novel Power Allocation Method for Nonorthogonal Multiple Access in Cellular Uplink Network(2017, conference)~~

Based on particle swarm optimization with genetic algorithm, NOMA power allocation algorithm을 제시함.(무슨 내용인지 잘모르겠음..)

1. ~~The Performance of Successive Interference Cancellation in Random Wireless Networks(2014, journal)~~

HCN(Heterogeneous Cellular Networks) with non-accessible base station에서 SIC gain을 평가함.

1. N. Mangalvedhe, R. Ratasuk, A. Ghosh," NB-IoT deployment study low power wide are a celluar IoT," Proc. IEEE Symposium on Personal, Indoor, and Mobile Radio Communic ations(PIMRC), Valencia, Spain, pp. 1-6, Sept. 2016

Simulation parameter setting reference

1. Narrow Band Internet of Things(2017, journal)

Simulation parameter setting reference(2)

1. ~~Coordinated Multipoint-Based Uplink Transmission in Internet of Things Powered by Energy Harvesting(2018, journal)~~

최초로 energy harvesting을 이용한 uplink CoMP방식을 소개함.

1. ~~Coordinated Direct and Relay Transmission Using Uplink NOMA(2018, journal)~~

Relay가 CCU와 CEU의 채널 상태에 따라서 decoding순서를 정하고, 재전송할때 ergodic sum capacity를 측정함. CCU와 Relay로부터 BS까지 거리가 동일하다는 가정.

1. ~~Coordinated Uplink Transmission for Cooperative NOMA Systems(2018, conference)~~

user 2개가 desired throughput이 다를 때, relay에서 받아서 user 2개의 information을 superposition해서 전송하는 방식

1. ~~Non-Orthogonal Multiple Access in Downlink Coordinated Two-Point Systems(2014, journal)~~

Downlink STBC NOMA scheme

1. ~~Performance of the LTE Uplink with Intra-Site Joint Detection and Joint Link Adaptation(2010, conference)~~

Uplink에서 intra site spatial modulation scheme을 사용할 때 performance를 조사함.

1. ~~Implementation and Analysis of CoMP in 3GPP LTE System Level Simulator(2011, conference)~~

Design & implement Matlab based CoMP scenario

1. ~~Non-Orthogonal Multiple Access in Coordinated Direct and Relay Transmission(2015, journal)~~

parameter setting paper, 내용은 downlink에서 BS가 superposition으로 2개 user의 정보를 전송하고, relay user가 주변의 user에게 재전송하겠다 것. SNR을 50dB까지 표시함.. 어차피 downlink관련한 것이기 때문에 내용면에서는 쓸모가 없더라도 simulation parameter를 설정하는데 사용.

1. An Incremental Relaying Approach for Superposition Modulated Cooperative Transmission(2009, conference)
2. Cooperative Transmit Diversity Based on Superposition Modulation(2005, journal)
3. Charlotte Hucher, Ghaya Rekaya-Ben Othman, Ahmed Saadani, "New protocols for the cooperative MAC", Signals Systems and Computers 2008 42nd Asilomar Conference on, pp. 985-989, 2008.(Conference)
4. Yue Ma, Lihua Li, Jin Jin, Yijing Liu, "A novel network coded relay-assisted Hybrid-ARQ scheme", Consumer Communications and Networking Conference (CCNC) 2013 IEEE, pp. 455-459, 2013.(Conference) – network coding을 활용한 SM HARQ scheme.
5. Xuanxuan Lu, Tiffany Jing Li, Yang Liu, "Multiuser cooperative transmission through superposition modulation based on braid coding", Acoustics Speech and Signal Processing (ICASSP) 2015 IEEE International Conference on, pp. 3128-3132, 2015.(Conference)
6. Superposition Modulation-Based Cooperation for Oversampled OFDM Signals(2017, journal) – downlink OFDM이라서 크게 상관없는 듯
7. Minimum Power Multicast Beamforming With Superposition Coding for Multiresolution Broadcast and Application to NOMA Systems(2015, journal)
8. A Cooperative Uplink Transmission Technique With Improved Diversity–Multiplexing Tradeoff(2015, journal) – multiuser diversity and relay selection diversity gain을 비교함. SM을 활용해서 새로운 아이디어를 제공하는 방식은 아님...
9. Sandeep Narayanan, Marco Di Renzo, Fabio Graziosi, Harald Haas, "Distributed Spatial Modulation: A Cooperative Diversity Protocol for Half-Duplex Relay-Aided Wireless Networks", Vehicular Technology IEEE Transactions on, vol. 65, no. 5, pp. 2947-2964, 2016.(journal)
10. Xuanxuan Lu, Jing Li, Yang Liu, "Cooperative Transmission Through Signal-Superposition-Based Braid Coding", Vehicular Technology IEEE Transactions on, vol. 65, no. 5, pp. 3100-3114, 2016.(journal)