Building the NOMA Simulation Model for Mac Layer Research

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I. Status quo

Briefly, by the previous effort in literature survey, we summarize related work as follows. Some studies investigate non-orthogonal multiple access (NOMA) by theoretical models, which are extended from shannon capacity model. Based on theoretical models, the rule that the optimal order for SIC decoding is same as the increasing order of $\frac{|h|^2}{N}$. A NOMA/Multiple-Input Multiple-Output (MIMO) scheme is proposed to achieve further capacity gain. Throughput balance of the cell-edge and interior users by using SIC in the cellular downlink.

Other works show SIC performance of simulations with respect to physical layer design has significant diffrence compared to the theoretical model. To proceed with research in MAC-layer, a working simulation model based on existing techniques are built to capture the practical performace trad-off in NOMA.

II. Key new insight

1) In Fig. 1, error propagation in existing NOMA PHY techniques (SIC) due to successive decoding of multiplexed signals needs to be taken into consideration in the simulation model. As In the theoretical model, the data of previous stages can be fully decoded regarless of the power allocation. 2) The impact of modulation/coding scheme (MCS) selection as well as the power allocation factor (PAF) among NOMA users (users that share the same resource block) also needs to be taken into consideration in the simulation model. 3) For a two-user NOMA system, pairing of users for sharing each resource block should ensure that the bit error rates (BERs) achieved at each user are within the tolerable range when the sum rate is being maximized.

III. Main achievement

We have built a physical-layer simulation platform for single- antenna NOMA with consideration of modulation, channel coding, and multipath channels based on SIC. We have obtained the desired MCS/BER model for two-user NOMA in the two-stage decoding scheme. We have investigated a simple scheduling algorithm for pairing users in each OFDM resource block such that the BERs of all users can satisfy the desired constraint.

IV. How it works

The physical layer simulation is constructed by the system architecture shown in Fig. 2. In this system, the receiver can only extract two layer of multiplexed data.

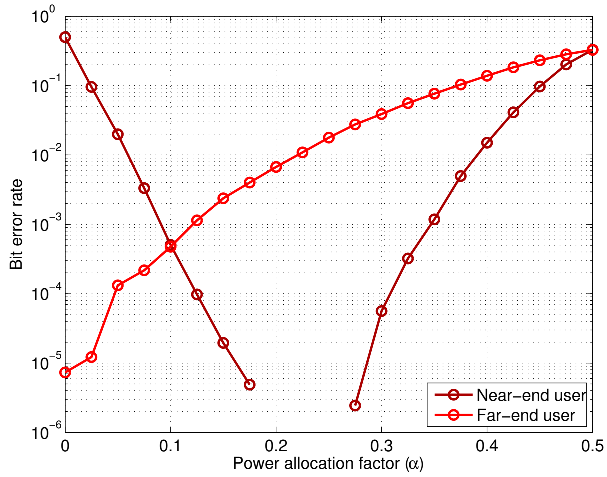

Fig. 1: BER for different power allocation factor

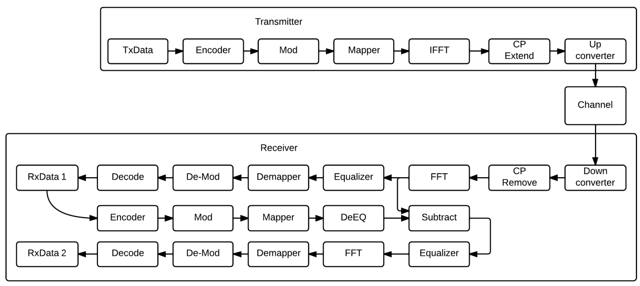

Fig. 2: simulation architecture

The system architecture is build with following functional blocks. 1)TxData generator: generates binary random bits for transmission, 2)Encoder: encode the data by convolutional coding method, 3)Modulator: modulates bits into symbols, 4)IFFT: maps the frequency domain signals to time domain samples, 5)Cyclic Prefix: appending cyclic prefix, 6)Channel: implement white noise and multipath enviornments, 7)Equalizer: to compensate the effect of channel.

Fig. 3 shows the highest order of MCS that the users can achieve in given BER constraint for different channel condition (note that axis has minus sign.) Here the BER constraint is set to be 10^{-4}.

To provide quality service in wireless multiple access

Algorithm 1 Scheduling transmission pairs iteratively

Input: a set of user equipments, i.e. $\mathbf{V}$
Initial: $CS \leftarrow \varnothing$ \\schedule set
Sort UEs by its pathloss increasingly.
  $\mathbf{V}' = \{[v_1\, v_2 ... v_n] | PL(v_i) \leq PL(v_j) \forall i < j\}$
While $\mathbf{V}'$ is not empty
  $u = \mathbf{V}'.first()$ \\select the first element
  For $r \in \mathbf{V}',\ r \neq u$
    If $pair(u,\ r)$ is feasible for given constraint
      $\mathbf{M} = pair(u,\ r).getMCS()$ \\feasible MCSs
      For $W_m, m \in \mathbf{M}$
        If $W_m > best$
          $best \leftarrow W_m$
          $r' \leftarrow r$
        End If
      End For
    End If
  End For
  If v' exists \\u can form a pair.
    $\mathbf{V}' \leftarrow \mathbf{V}' \backslash \{r', u\}$, $CS \leftarrow CS \bigcup \{r', u\}$
  Else
    $\mathbf{V}' \leftarrow \mathbf{V}' \backslash \{u\}$, $CS \leftarrow CS \bigcup \{u\}$
  End If
End While
Return $best$, CS

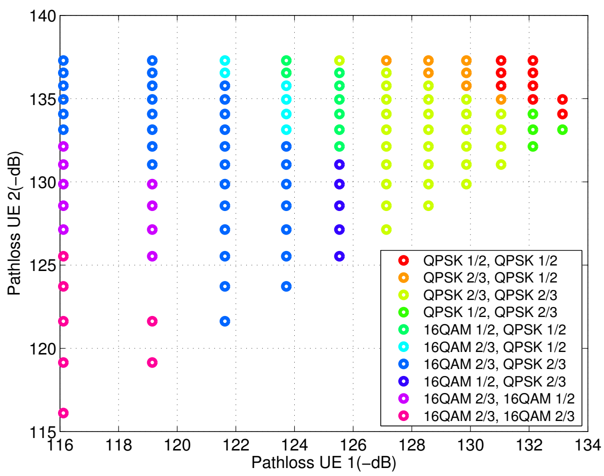

Fig. 3: MCS supported for BER constraint 10^{-4}

network, its essential to make proper scheduling between users when the resources is limited. Fig. 4 shows the topology of 12 users are randomly scattered in 2800 square meter plane. Each user has to transmit at least once and we have to schedule all users in 6 resource blocks with 2 users in each with no overlapping. Fig. 4 shows the schedule result by algorithm 1 Pairs of users are painted with different color.

V. Risk limitation and assumptions

The base station transmit multiplexed signal from two independent sources. The receiver is aware of number of multiplexed user data and thus no further detection is needed to identify the depth of decoding order. Full channel state condition is assume in the simulation, no channel estimation

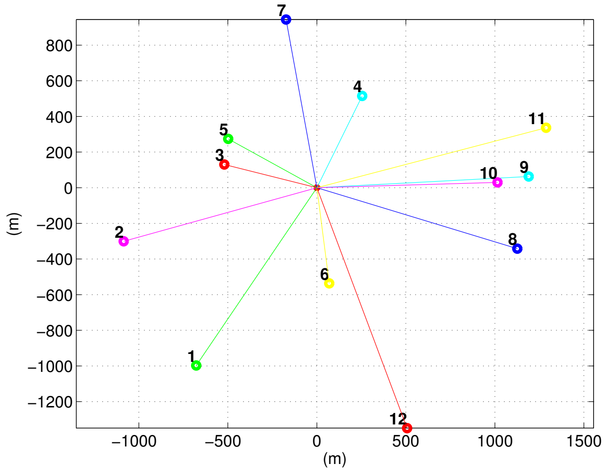

Fig. 4: Scheduled transmission pairs by Alg. 1

or receiver manufacture defect is taken into consideration. As an investigation of the limitation of NOMA with SIC, the BS can only transmit signals of two sources utmost.

VI. Quantitative impact

We have found that a 20% performance gain in the (weighted) sum rate can be achieved when the paired users have a path-loss ratio of 10. The performance gain increases as the difference in the channel condition (path loss) keeps increasing. Best MCS for two-user NOMA based on the obtained MCS/BER model for two-user NOMA (right figure), the proposed scheduling algorithm can pair users with 91.67% optimality (for a 12-user downlink scenario) without incurring the complexity needed in exhaustive search.

VII. End goals

Based on the NOMA simulation model and the two-user scheduling algorithm that we have completed so far, our goal in the future is to explore more generic problems and algorithms for resource allocation, scheduling, and power control at the MAC layer for optimizing the performance of NOMA under the desirable computation complexity and communication overheads. The simulation model for single-antenna NOMA will be extended to MIMO such that clustered-based resource allocation and scheduling can be investigated in the future.

VIII. Conclusion

We have built a simulation model for NOMA based on SIC that takes into consideration MCS selection, error propagation, and power allocation into consideration. The simulation model serves as the basis for our preliminary investigation at the MAC layer for two-user pairing and scheduling in each OFDM resource block. Our preliminary results have substantiated the potentials of NOMA in the next-generation communication system and paved the ground for continuing investigation of various MAC layer research issues in the future.