Weekly Report (2009-10-11)

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1. Research Work

Based on further literature study and discussion with Charlie, we found that little work has been conducted to introduce interference cancelation into SINR-based scheduling problem and came up with the following potential issues.

We consider the scenario of multiple-transmitter-single-receiver with successive-interference-cancelation. Perfect cancelation, which means a signal can be perfectly canceled if its $SINR$ value is above some threshold, is assumed for simplicity of analysis. An order of interference cancelation is scheduled for n signals and P_i is the transmission power of i^{th} canceled signal. Then, the $SINR$ value for the i^{th} canceled signal can be computed as $SINR_i = \frac{P_i/d_i^\alpha}{N_0+\sum_{j>i} P_j/d_j^\alpha}$. Here N_0 is additive-white-gaussian-noise (AWGN) and d_i (d_j) is the distance from i^{th} (j^{th}) transmitter to receiver.

1) **Issue 1**: *Minimize total energy-consumption with guaranteed SINR value*. We assume that one signal i can be successfully received and decoded by the receiver if and only if its $SINR_i$ value is above β. (This is a binary relation.) Please be noted that $SINR_i$ only counts the remaining non-canceled signals as the interference. Thus the order of interference cancelation will affect the total energy-consumption. The key is to find out an order of signals that optimize the total energy-consumption. The optimization problem can be formalized as follows.

$$\begin{aligned} Minimize \quad & \sum_{i=1}^{n} P_i \\ s.t. \quad & SINR_i \geq \beta \ (i = 1, ..., n) \end{aligned}$$

   One natural way is to solve this problem in a reverse direction. Suppose the order should be $1, ..., n$. We calculate the value of P_i with $\frac{P_i/d_i^\alpha}{N_0} = \beta$ for each signal and find out the one with minimal value. Then that signal (P_n) will be the last to be canceled. In the next step, the value of P_i with $\frac{P_i/d_i^\alpha}{N_0+P_n/d_n^\alpha} = \beta$ is calculated for each signal and the minimal one will be selected as the $(n-1)^{th}$ canceled.
   So, in general, the m^{th} step of our mechanism is to calculate the value of P_i with $\frac{P_i/d_i^\alpha}{N_0+\sum_{j>m} P_j/d_j^\alpha} = \beta$ for each signal and find out the one with minimal value. Then that signal will be the m^{th} to be canceled.

2) **Issue 2**: *Maximize overall throughput with constraint power-consumption*. In a more realistic interference model, the interference relation is binary based on $SINR$ value. In AWGN channels, which is most commonly studied in related areas, the channel capacity should be calculated as $B \log(1 + SINR)$, in which B is the channel bandwidth. Here, we assume that the transmission power for each signal should be limited by an upper-bound P_M. The objective is to maximize the overall throughput of all uploading channels from transmitter to the receiver. The optimization problem can be formulated as follows.

$$\begin{aligned} Maximize \quad & \sum_{i=1}^{n} B \log(1 + SINR_i) \\ s.t. \quad & 0 \leq P_i \leq P_M \ (i = 1, ..., n) \end{aligned}$$

   The order of cancelation still matters here.

3) **Issue 3**: *Balanced power-consumption with guaranteed throughput*. We can further consider the fairness in energy-consumption on each transmitting node. We want to minimize the mean square deviation of transmission power while maintaining a threshold of throughput for overall channels or for each channel.
   Suppose the average energy consumption for each transmitting node is $E(P)$. Then the optimization problem can be formulated as follows.

$$
\begin{aligned}
Minimize \quad & \sum_{i=1}^{n}(P_i - E(P))^2 \\
s.t. \quad & \sum_{i=1}^{n} B\log(1+SINR_i) \geq C \\
& or\ B\log(1+SINR_i) \geq C_i\ (i=1,...,n)
\end{aligned}
$$

2. Paper Study

Most interference-cancelation related research goes in a engineering fashion, which may not be our style in current stage. And only a few theoretical papers have been published in communication-society.

[1] studies the minimization of power consumption at mobile terminals in broadband uplink CDMA transmission with successive interference cancelation (SIC). It is the first one to propose the joint optimization of power control and ordering of user detection. A so-called approximation algorithm is presented but with no theoretical approximation ratio.

[2] addresses on the linear ordering problem with cumulative costs (LOPCC). The user detection with SIC serves as an example of motivation. They formulate the problem with complete bigraph and transit it into classic mathematical problems. I have not finished the whole paper yet.

[3] deals with the LOPCC problem with Tabu search. Cumulative costs are organized as a weighted matrix. A heuristic algorithm based on the Tabu Search is designed with good performance in numerical analysis.

The current problem in these researches is that only heuristic algorithms are proposed. We can only assess the performance with numerical analysis. Some approximation algorithm with guaranteed approximation ratio is desirable for current status.

References

[1] N. Benvenuto, G. Carnevale and S. Tomasin, *Joint Power Control and Receiver Optimization of CDMA Transceivers Using Successive Interference Cancelation*, IEEE Transactions on Communications, vol. 55, NO. 3, March, 2007.

[2] L. Bertacco, L. Brunetta and M. Fischetti, *The Linear Ordering Problem with Cumulative costs*, European Journal of Operational Research 189 (2008) p. 1345-1357.

[3] A. Duarte, M. Laguna and R. Marti, *Tabu Search for the Linear Ordering Problem with Cumulative Costs*, Computational Optimization and Applications, 2009.