Weekly Report (2009-12-31)

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I. Joint Latency and Power Minimization in Data Aggregation with Successive Interference Cancellation under the SINR model

Given with a graph G with n nodes, which is denoted as V with v_n as the sink node, we try to minimize both aggregation latency and power consumption with respective weights. We finally formulate the problem model as an optimization problem.

$$
\begin{aligned}
minimize_{E,S,P} \quad & (\sum_{t=1}^{n} f(s^t))^a (\sum_{t=1}^{n} \mathbf{1}^T P^t \mathbf{1})^b \\
s.t. \quad & E \times \mathbf{1} = [1, ..., 1, 0]^T \\
& E^n = \mathbf{0}_{n\times n} \\
& \sum_{t=1}^{n} s^t = E \\
& s^j \times s^i = \mathbf{0}_{n\times n} \ \forall i \leq j \\
& 0 \leq P_{ij}^t \leq P_{max} s_{ij}^t \quad \forall t, i, j \in [1, n] \\
& G_{ij} P_{ij}^t - \beta \sum_{u\neq i} \sum_{w \neq j} G_{uj} P_{uw}^t - \beta \sum_{u>i} G_{uj} P_{uj}^t - \beta N_0 \geq \Phi(s_{ij}^t - 1) \quad \forall t, i, j \in [1, n]
\end{aligned}
$$

Here, E is a $n \times n$ matrix with the property that $E_{ij} = 0$ means there is no link between node i and j while $E_{ij} = 1$ means there is a link directing from node i to node j. S is a sequence of n $n \times n$ matrices. Each $s^t \in S$ stands for a schedule in time slot t. $s_{ij}^t = 1$ means link e_{ij} is scheduled in time slot t while $s_{ij}^t = 0$ means link e_{ij} is not scheduled in time slot t. P is also a sequence of n $n \times n$ matrices and P_{ij}^t stands for the power assignment for link e_{ij} in time slot t. f is an indicator function that

$$
f(s) = \begin{cases} 1 & \text{if } \mathbf{1}^T \times s \times \mathbf{1} > 0 \\ 0 & \text{if } \mathbf{1}^T \times s \times \mathbf{1} = 0 \end{cases}
$$

So $\sum_{t=1}^{n} f(s^t)$ is the aggregation latency. a and b are weights in the objective function for aggregation latency and power consumption respectively.

The 1^{st} constraint ensures that each node transmits exactly once except for the sink node. The 2^{nd} constraint makes sure that there is no circle in the graph. As a result, the above two constraints guarantee that E constructs an aggregation tree. The 3^{rd} constraint stands for the requirement that each link is scheduled exactly once. And according to the 4^{th} constraint, once a node transmits, it will not be the receiver in future. The 5^{th} and 6^{th}

constraints are for the power assignment and SINR requirement respectively. Here, Φ is a big positive number and G is the path gain matrix as follows

$$G = \begin{bmatrix} 1 & 1/d_{12}^{\alpha} & ... & 1/d_{1n}^{\alpha} \\ 1/d_{21}^{\alpha} & 1 & ... & 1/d_{2n}^{\alpha} \\ ... & ... & ... & ... \\ 1/d_{n1}^{\alpha} & 1/d_{n2}^{\alpha} & ... & 1 \end{bmatrix}$$

$\sum_{u \neq i} \sum_{w \neq j} G_{uj} P_{uw}^{t}$ is the cumulative interference from concurrent scheduled links with different receivers from e_{ij} while $\sum_{u>i} G_{uj} P_{uj}^{t}$ is the remaining non-canceled interference from concurrent scheduled link with the same receiver. Note that successive interference cancellation is carried out in ascending order of node number here.

In conclusion, our problem is composed of three parts: tree construction, link scheduling and power control.

1) *Tree Construction*: Constraints 1 and 2.
2) *Link Scheduling*: Constraints 3 and 4.
3) *Power Control*: Constraints 5 and 6.

As the original Minimum-Latency-Aggregation-Scheduling (*MLAS*) problem is already NP-hard, our extended problem will not be easy to tackle. The current optimization problem is too complicated with three variables: E, S and P. And each variable is in a form of matrix or set of matrix. So it would be better to decompose the original problem into subproblems as in [1] and [2].

On the other hand, the main challenge here is how to model the joint tree construction, link scheduling and power control while implementing successive interference cancellation. Although the model is correct this time, the solution to the problem is even more difficult than the modeling as it can be classified into Mixed Integer and Linear Programming (*MILP*) problem.

II. Power-Constrained Uplink Capacity Maximization in Cellular Networks with Successive Interference Cancellation

The problem is discussed in my project for CSIS9602. However, the model is strictly mapped for single cell scenario. The multiple cell case with other concurrent scheduled cells is more challenging. The reason is that Other Cell Interference (*OCI*) should be considered.

Compared to *Joint Latency and Power Minimization in Data Aggregation with Successive Interference Cancellation under the SINR model*, *Power-Constrained Uplink Capacity Maximization in Cellular Networks with Successive Interference Cancellation* is easier to solve.

III. Paper Study

[1] is a good survey on the application of optimization in Network Utility Maximization (*NUM*) problem with stochastic events. However, continuous network flow is assumed in [1] which is different from our binary SINR model in *MLAS* problem. Some but not all technique is learned from [1] to establish our model.

A throughput optimization problem in multihop wireless networks is discussed in [2] with joint link scheduling and power control. The problem is mapped into a Mixed Integer and Linear Programming (*MILP*) problem. The modeling of link schedule and power control is insightful for our model.

REFERENCES

[1] Y. Yi and M. Chiang, *Stochastic Network Utility Maximization*, In European Transactions on Telecommunications, 2008, 00: pp. 1-22.

[2] J. Tang, G. Xue, C. Chandler and W. Zhang, *Link Scheduling with Power Control for Throughput Enhancement in Multihop Wireless Networks*, In IEEE Transaction on Vehicular Technology, vol. 55, NO. 3, May 2006.