# Weekly Report (2009-11-01)

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## 1. Problem Model

Given with a node set $V$ with $|V| = n$ randomly distributed wireless nodes and a sink node $v_0$, which releases SQL-like queries into the network, all data in $V$ should be aggregated to $V_0$ with some convergecast.

We can have two criteria to guide the design of an aggregation algorithm: latency and energy-consumption.

- **Latency**: in many applications, data should be aggregated to the sink timely before been invalidated. So we may need to minimize the aggregation latency or to maximize the network throughput, which is the target of our latest paper. However, if Successive Interference Cancellation (SIC) is implemented without energy constraint on sensor nodes, only one timeslot will be enough to do the job with well-designed power control.
- **Energy-consumption**: as we know, sensor nodes are always energy constrained. As a consequence, we may want to minimize the energy-consumption for each round of aggregation in order to maximize the life-span of sensors. In this case, there is no difference between mechanisms with and without SIC. The optimal solution will be a Minimum Spanning Tree with $d^\alpha$ as the link weight.

Combining the above two criteria, we would like to minimize the aggregation latency while also minimizing the energy-consumption. That equals to maximizing the amount of data aggregated to the sink within one time-unit with one unit of energy. SIC will be applied to this problem and two steps will be required. Firstly, a proper topology (set of links $E$) should be generated. And then, an efficient link scheduling with SIC should be designed.

The problem should be on the basis of the SINR interference model, under which the condition for a successful transmission over link $i$ is as follows.

$$SINR_i = \frac{P_i/d_{ii}^\alpha}{N_0 + \sum_{j\in\Lambda_{i1}/\{i\}, j>i} P_j/d_{ji}^\alpha + \sum_{k\in\Lambda_{i2}/\{i\}} P_k/d_{ki}^\alpha} \geq \beta$$

Here, $P_i$ ($P_j$, $P_k$) is the transmitting power of link $i$ ($j$, $k$). $d_{ii}$ ($d_{ji}$, $d_{ki}$) is the distance from transmitter of link $i$ ($j$, $k$) to receiver of link $i$. $\alpha$ is the path loss ratio, which is between 2 and 6. $N_0$ is the ambient noise. $\Lambda_{i1}$ is the set of concurrent transmitting links sharing the same receiver with link $i$. $\Lambda_{i2}$ is the set of other concurrent transmitting links. $j > i$ means that link $i$ is canceled ahead of link $j$. Perfect interference cancellation is assumed.

Then we define our problem as an optimization problem as follows.

$$\begin{aligned}
&minimize && T \times P \\
&s.t. && \exists S = \{S_1, S_2, ..., S_T\} \\
& && i \neq j \Rightarrow T(S_i) \cap T(S_j) = \emptyset \\
& && i < j \Rightarrow T(S_i) \cap R(S_j) = \emptyset \\
& && \cup_i T(S_i) = V \\
& && R(S_T) = \{V_0\} \\
& && P = \sum_{V_i \in V} P_i \\
& && SINR_i \geq \beta, (i = 1, 2, ..., n)
\end{aligned}$$

Here, $T$ is the aggregation latency and $P$ is the overall energy-consumption. $S$ is the link schedule and $S_i$ is the set of links, which is represented as a two-tuple of transmitter and receiver, scheduled in time $i$. $T(S_i)$ is the set of transmitters in $S_i$ and $R(S_i)$ is the set of receivers in $S_i$.

The above problem definition may not look like a classic optimization problem as we bring in the constraints for topology construction.

## 2. Paper Study

Although there is no work in data aggregation implemented with interference cancellation, there have been some valuable results in CDMA systems. Especially on how to alleviate the Other Cell Interference (OCI) in multicell CDMA systems.

- [4] considers the minimization of uplink power consumption in CDMA systems with QoS constraints and perfect interference cancellation. The problem is formulated as a constraint optimization problem with total power consumption as the objective function and QoS requirements as the constraint functions. Here, QoS is characterized as BER which is determined by $\frac{E_b}{N_0}$. ($(\frac{E_b}{N_0})_i = \frac{W}{R_i}\frac{h_i P_i}{N_0 W + \sum_{j=i+1}^{N} h_j P_j}$) As a result, the constraint is the combination of SINR value and data rate. On the basis of rigid theoretical analysis, they claim that channel gain is more influential factor than rate order in deciding the cancellation order, which implies that we should cancel the signals according to descending order of channel gains. However, this paper has two drawbacks. First, only single cell multiple access interference is taken into account. In a more sophisticated and realistic application, multiple cells may schedule multiple uplinks at the same time. Thus, at the base-station side, inter-cell interference should also be considered. Second, perfect interference cancellation is assumed. This contains the hidden assumption that perfect channel state information should be acquired, which is not applicable in most wireless systems.
- In [3], the power-optimization problem is extended into DS-CDMA systems with imperfect interference cancellation and diverse QoS requirements. A closed form of solution for single cell is firstly presented followed by its extension in multiple-cell scenario. Note that imperfect interference cancellation means that we should account for the residue of previous canceled signals. Besides, in DS-CDMA, a spreading factor should be brought into the calculation of BER value.
- [1] addresses the interference cancellation in cellular systems from a different angle. It aims to maximize the network capacity with constraint power-consumption and fixed BER. An optimal power control mechanism, which can tolerate high degree of channel estimate error, is proposed. In addition, the inter-cell interference in multicell networks is also tackled. Analysis demonstrates that the novel scheme can double the capacity compared to the case with no interference cancellation and the overall transmission energy can be reduced.
- Different from the above works, which use BER as the constraint function in the optimization problem, [2] makes use of SINR value as the constraint. Perfect interference cancellation is assumed and spreading factor is taken into consideration aimed on broadband CDMA systems. The problem is formulated into a joint optimization of transmit power and detection order (JOPCO) and the solution is presented. Numerical results show that this work provides energy saving of up to 7 dB in absence of scrambling and up to 3 dB in presence of scrambling compared to existing mechanisms on SIC.
- [5] explores the network throughput on the downlinks instead of uplinks in multi-cell CDMA systems. The difficulty in downlinks-scenario is that, different from uplinks-scenario in which base-station is located at the center of cell, mobile users may reside on the edge of cells. That implies more difficulty in bounding the interference from other cells for the users. Intercell Interference Cancellation (ICIC), which requires coordination among base-stations, is targeted to increase the network capacity by suppressing the Other Cell Interference (OCI). However, this paper assumes a MISO interface at the mobile user side, which means base station has multiple antennas transmitting to the user concurrently.

## References


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