Weekly Report (2009-10-18)

Hongxing Li

1. Paper Study

- The transmission capacity of wireless ad-hoc networks is analyzed in [1] when successive interference cancellation (SIC) is applied. It should be noted that the transmission capacity in this paper is defined as *the maximum spatial intensity of successful transmissions such that the outage probability does not exceed some specified threshold*. Both upper bounds and lower bounds for perfect and imperfect interference cancellation are presented in closed-form. The result demonstrates that SIC is more effective if applied with direct sequence spread spectrum. And the imperfect SIC will greatly degrade the performance.
  However, [1] has several limitations:
  1) All the analysis are based on the assumption that nodes are distributed in Poisson process. As a consequence, the analytical results are not feasible for other distributions. A more strict theoretical bound for arbitrary topology is more desirable.
  2) Binary SINR model, which means that a transmission is successful if and only if the SINR value is above some threshold, is assumed. We can extend the work with Shannon-Hartley theorem, in which channel capacity is proportional to $\log(1 + SINR)$. Of course, this will not be any trivial job.
  3) Just analytical result on the basis of probability. Not strict upper or lower bound for arbitrary cases.
- Besides interference cancellation, there have been other efforts on physical or MAC layer trying to increase the achievable system throughput.
  - [2] argues that interference cancellation incurs significant computation complexity and cannot be implemented with commodity hardware. As a result, they aims on a different perspective: channel width. Recall that, according to Shannon-Hartley theorem, the channel capacity is computed as $C = B\log_2{(1+\frac{S}{N})}$, where B is the bandwidth of channel, S is the total received signal power over the bandwidth and N is the total noise or interference power over the bandwidth. Then, interference cancellation focuses on the $\frac{S}{N}$ part. It increases the SINR value of some received signal by canceling the interference caused by other signals. For n transmitters, the overall achievable capacity is bounded as $\sum_{i=1}^{n} C_i \le B\log_2{(1+\frac{\sum_{i=1}^{n} S_i}{N})}$. However, in [2], B becomes the target, which is divided into a bunch of orthogonal variable-width channels. Each signal will be assigned to one of these channels. Thus, there will be no interference among the signals. The overall achievable capacity can be rewritten as $\sum_{i=1}^{n} C_i \le \sum_{i=1}^{n}(B_i \log_2{(1+\frac{S_i}{N})})$. Although the variable-width approach cannot perform better than interference cancellation in most cases, it shares the same optimal capacity value with interference cancellation and has a significant increase compared to any fixed-width TDMA schemes.
  - Message-in-Message (MIM) technology is another way to improve the network capacity. In [3], the authors demonstrate that arriving order of Signal-of-Interest (SoI) and interference signals matters a lot in detecting and recovering the SoI. Different arriving order of SoI and interference will require different SINR value to decode SoI, resulting in different channel capacity and energy consumption.
  - [4] handles the collision in wireless networks. Since it has been shown that CSMA/CD and RTS/CTS achieve bad spatial reuse, a novel collision detection and notification mechanism, which is called CSMA/CN, is introduced. The detection takes place at the receiver side. Once collision is detected, a special short packet is sent back to transmitter as a notification. Simulation based on USRP/GNURadio testbed confirms the feasibility and performance gains. However, there are one important drawback in this paper that two antennas are required on the transmitter. The additional antenna may serves in an orthogonal frequency-band, which brings no interference.

2. Potential Topic

In addition to the three topics proposed in last report, we can further extend the work into imperfect interference cancellation scenario, which may be more realistic but also more complicated.

In real applications, each cancellation for any signal will left some residue in the combined signal. Without loss of generality, we have $0 \le z \le 1$ which is the residue ratio compared with original signal. It is not hard to see that if $z = 0$, the cancellation is perfect and if $z = 1$, no interference cancellation is applied. So imperfect cancellation is the case in which $0 < z < 1$. Suppose the set of all signals is S and the set of already canceled signals is S_c. Then the successful reception of a signal i in $S - S_c$ is as follows.

$$\frac{P_i/d_i^\alpha}{N_0 + \sum_{j \in S_c}(zP_j/d_j^\alpha) + \sum_{k \in S - S_c - \{i\}}(P_k/d_k^\alpha)} \geq \beta$$

This is the formula for $SINR_i$ in last report. If we substitute $SINR_i$ with this formula, all three problems in last report will be different.

References

[1] S.P. Weber, J.G. Andrews, X.-Y Yang and G. de Veciana, *Transmission Capacity of Wireless Ad Hoc Networks With Successive Interference Cancellation*, IEEE Transactions on Information Theory, vol. 53, NO. 8, Aug. 2007.

[2] R. Gummadi, R. Patra, H. Balakrishnan and E. Brewer, *Interference Avoidance and Control*, In Proceedings of HotNet'08, Oct. 6-7, 2008, Calgary, Alberta, Canada.

[3] N. Santhapuri, J. Manweiler, S. Sen, R.R. Choudhury, S. Nelakuduti and K. Munagala, *Message in Message (MIM): A Case for Reordering Transmissions in Wireless Networks*, In Proceedings of HotNet'08, Oct. 6-7, 2008, Calgary, Alberta, Canada.

[4] S. Sen, N. Santhapuri R.R. Choudhury and S. Nelakuditi, *Moving Away from Collision Avoidance: Towards Collision Detection in Wireless Networks*, In Proceedings of HotNet'09, Oct. 22-23, 2009, New York, USA.