Spectrum Sharing and Leveraging Randomness in Large Wireless Networks

Amir K. Khandani
Coding and Signal Transmission Laboratory
E&CE Department, University of Waterloo

In wireless networks, multiple source/destination nodes share a common transmission channel where simultaneous transmissions (frequency reuse) can occur, but at the cost of causing interference among active links. Analysis/design and proof of optimality in such configurations even in their simplest forms have been among the most difficult problems facing the Information Theory community for many years. This talk first studies the asymptotic behavior of some key configurations occurring in wireless networks. It is shown that as the number of nodes increases, wireless networks become much more tractable. This is based on leveraging the network randomness where among the many, all asymptotically optimum network configurations, one is selected which enjoys a simple analysis/design. Five configurations are briefly discussed: (1) time varying Raleigh fading channel, (2) Broadcast channel with multiple transmit antennas, (3) multi-link interference channel (without interference cancellation), (4) multi-antenna multi-relay channel, and (5) scheduling to exploit multi-user diversity subject to delay constraints. In (1), it is shown that, the capacity assuming AWGN/Raleigh fading with Markovian memory and periodic causal feedback can be achieved by scaling of a single Gaussian codebook. In spite of this promising result, the requirement for repeated feedback may still be a limiting factor. Subsequently, it is shown that by proper scheduling of users and subject to some mild conditions on the channel memory, it is possible to asymptotically achieve optimality. In (2), it is shown that the capacity can be achieved with simple scheduling/beam-forming strategies and necessary/sufficient results are presented for the minimum required amount of feedback. In (3), it is shown that the best result reported in the literature for a large network using relay nodes/routing and a central network controller can be achieved without relays/routing and without the need for a central network manager. In (4), the asymptotic capacity (for large number of relays) is derived which is shown to be achievable with a simple signaling structure. In (5), it is shown that surprisingly it is possible to achieve the optimum performance, while keeping the delay at the minimum possible value (minimum delay is traditionally achieved using Round-robin scheduling which completely ignores the multi-user diversity). The second part of the talk discusses the practical application of these theoretical results. Although IEEE8021.n and IEEE802.16d/e/j are very recent and even in parts still not finalized, industrial world has already started looking into more advanced wireless technologies, in specific IEEE802.16m and GiFi. These new standards, still at their earliest stages, aim at realizing much higher

spectral efficiencies (bit rates of 1Gig-bits/sec). Over the last few years, MIMO systems have been extensively studied, however, the vast majority of these studies have decoupled the MIMO design problem from that of frequency sharing, where bandwidth/time is divided to non-overlapping segments to reduce the interference. This talk will briefly review how such a dividing of time/frequency is in most cases inherently suboptimum. Examples are provided showing that the effect of spectrum/time sharing in MIMO systems can be quite significant, paving the way towards a much better usage of the scarce spectrum.

Biography: Amir K. Khandani received his M.A.Sc. degree from University of Tehran, Tehran, Iran, and his Ph.D. degree from McGill University, Montreal, Canada, in 1985 and 1992, respectively. Subsequently, he worked as a Research Associate at INRS Telecommunications (Quebec University), Montreal, Canada, for one year. In 1993, he joined the Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, Canada, where he is currently working as a professor. Dr. Khandani is currently holding an NSERC Industrial Research Chair (funded by NSERC and Nortel Networks) on "Advanced Telecommunications Technologies" and a Canada Research Chair on "Wireless Systems". He is currently acting as an Associate Editor for the IEEE Transactions on Communications in the area of Coding and Communication Theory.