Chandra Nair

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APPOINTMENTS

Associate Professor of Information Engineering 2013-
Programme Director of Mathematics and Information Engineering (MIEG) 2014-
Director of Institute for Theoretical Computer Science and Communication (ITCSC) 2017-
Assistant Professor of Information Engineering 2007-2013
The Chinese University of Hong Kong

- Research interests: Network Information Theory, High-dimensional Probability Theory, Combinatorial Optimization
- Teaching: Signals and Systems, Engineering Mathematics, Random Processes, Probability Theory, Network Information Theory

Postdoctoral Researcher 2005-2007
Theory Group, Microsoft Research, Redmond

- Research: Phase transitions in the number partition problem, spatial mixing and approximate counting, broadcast channels

EDUCATION

PhD Electrical Engineering 2000-2005
Stanford University

- Thesis: "Proofs of the Parisi and Coppersmith-Sorkin conjectures in the random assignment problem"
- Principal advisor: B. Prabhakar (Stanford)
- Stanford Graduate Fellow (2000-2004), Microsoft Research Fellow (2004-2005)
- Research: Combinatorial optimization, Queuing systems and buffer management in computer networks, Information theory, Energy efficient communication in wireless networks

MS Electrical Engineering 1999-2002
Stanford University

B.Tech Electrical Engineering 1995-1999
Indian Institute of Technology, Madras

- Philips (India) & Siemens (India) prizes for the best academic record in Electrical Engineering

Nurture programme in mathematics 1995-1999
Institute of Mathematical Sciences, Madras

- Conducted by the national board of higher mathematics for students of the mathematics olympiad training camp.

AWARDS & HONORS

- 2018 IEEE Fellow
- 2017-2018 Information Theory Society distinguished lecturer
- 2016 Information Theory Society best paper award
- 2004-2005 Microsoft Graduate Fellow
- 2000-2004 Stanford Graduate Fellow
- 1999 Siemens(India) and Phillips(India) prize for best academic record (EE dept, class of 99)
- 1994-1999 National Science Talent Scholar
- Mathematical Olympiads:
  - 1994 First rank in the Indian National Mathematics Olympiad (INMO)
  - 1993 First Rank in the Regional Mathematics Olympiad (qualifier for the national one)
  - 1995 First Rank in the (national) Mathematics Olympiad conducted by the Association of Mathematics Teachers of India (AMTI)

THESES SUPERVISED

- Sida Liu – PhD 16 "Genie based outer bounds for interference channels" *currently at BNP Paribas*
- Lingxiao Xia – PhD 16 "On Tightness of Several Achievable Rate Regions in Network Information Theory" *currently at compareglobal*
- Geng Yanlin – PhD 12 "On the Evaluation of Marton's Inner Bound for Binary Input Broadcast Channels" *currently at ShanghaiTech University*
- Zizhou Wang – PhD 10 "On the tightness of inner and outer bounds for broadcast channels with three and more receivers" *currently at ASTRI*

TEACHING

Remark: Graduate classes are marked with a † sign.

- Signals and Systems: 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2016, 2017, 2018
- † Network Information Theory: 2008, 2011, 2014, 2016
- † Theory of Probability: 2010, 2013, 2015, 2017
- Random Processes: 2010†, 2016
- Advanced Engineering Mathematics: 2009
- Basic Circuit Theory: 2007

(INVITED) SEMINARS AND COLLOQUIA (recent, selected)

- Massachusetts Institute of Technology, LIDS Special Seminar, April 2018
- CMSA, Harvard University, Workshop on Coding and Information Theory, April 2018
- Princeton University, CISS Workshop, March 2018
- National University of Singapore, Beyond I.I.D. Workshop, July 2017
- Simon's Institute Berkeley, Information Theory Reunion Workshop, June 2016
- Institute Henri Poincare, Information Theory Program, Feb 2016
- Shannon Workshop, I.I.T. Bombay, Jan 2016
- Stanford University, ISL Seminar, May 2015
- University of Michigan, Ann Arbor, Electrical Engineering, April 2015
- Stanford University, Statistics Seminar, Feb 2015
- U.C. Berkeley, Probability Seminar, Feb 2015
- Unicamp Brazil, SP Coding Workshop, Jan 2015
- Princeton University, William Pierson Field Lecture, Oct 2014

PUBLICATIONS (selected)

Remark 1: For a more complete list of publications, please visit my homepage.
Remark 2: Due to the preferences of (mostly) some senior co-authors, the authors in **some** of the papers are **not listed** in alphabetical order. These papers are marked with a † sign.

Network Information Theory

- C. Nair, and M. Yazdanpanah, "Sub-optimality of superposition coding region for three receiver broadcast channel with two message sets", *IEEE International Symposium on Information Theory (ISIT)*, (2017), 1038-1042.
  Summary: This paper solves open problem 8.2 in Network Information Theory. The result and techniques open up a lot of interesting and promising avenues for future research.

- † C. Nair, H. Kim, and A. El Gamal, "On the optimality of randomized time division and superposition coding for the broadcast channel", *2016 IEEE Information Theory Workshop (ITW)*, (2016), 131–135.
  Summary: This paper solves the behavior of the capacity region around the corner points for a generic two receiver broadcast channel.

- C. Nair, L. Xia, and M. Yazdanpanah, "Sub-optimality of Han-Kobayashi achievable region for interference channels", *IEEE International Symposium on Information Theory (ISIT)*, (2015), 2416–2420.
  Summary: This paper solves a long standing open problem (open problem 6.4 in Network Information Theory).

- Y. Geng and C. Nair, "The capacity region of the two-receiver vector Gaussian broadcast channel with private and common messages", *IEEE Transactions on Information Theory*, (2014), 2087–2104.
  Summary: This paper develops a novel method for proving optimality of Gaussian distributions for optimization problems involving auxiliary variables appearing in network information theory. The basic idea of the method is to use the proof of sub-additivity (tensorization) of underlying functionals to determine optimality of Gaussians. It also solves open problems 9.2 and 9.3 in Network Information Theory. This paper obtained the *2016 Information Theory Society best paper award*.

- Y. Geng, A. Gohari, C. Nair, and Y. Yu, "The capacity region of classes of product broadcast channels", *IEEE Transactions on Information Theory*, (2014), 22–41.
  Summary: This paper shows the sub-optimality of the UV outer outer bound for broadcast channels, develops a powerful min-max theorem, utilizes the tensorization idea to provide converses, and obtains the most comprehensive classes of channels of discrete broadcast channels for which capacity region is characterized. Some of these ideas played a key role in developing the Gaussian optimality proof.

- V. Anantharam, A. Gohari, and C. Nair , "Improved cardinality bounds on the auxiliary random variables in Marton's inner bound", *IEEE International Symposium on Information Theory (ISIT)*, (2013), 1272–1276.
  Summary: This paper shows how a dual representation of the concave envelope can be used to improve cardinality bounds for the auxiliary variables in Marton's inner bound.

- Y. Geng, V. Jog, C. Nair, and Z. Wang, "An information inequality and evaluation of Marton's inner bound for binary input broadcast channels", *IEEE Transactions on Information Theory*, (2013), 4095–4105.
  Summary: This paper establishes an information inequality conjectured for a special case in 2008; which was established in a conference paper 2009 and generalized in 2010. This inequality was the starting point of my investigations into techniques for identifying the extremal distributions of Marton's inner bound; a study that has since broadened much further and driven many of the subsequent results.

- C. Nair, "On three receiver more capable channels", *International Symposium on Information Theory (ISIT)*, (2012), 378–382.
  Summary: This paper addresses open problem 5.2 in Network Information Theory and shows that the optimality of superposition coding under more-capable ordering does not extend to three receivers.

- C. Nair and Z. Wang, "The capacity region of the three receiver less noisy broadcast channel", *IEEE Transactions on Information Theory*, (2011), 4058–4062.
  Summary: This paper shows that optimality of superposition coding for less noisy ordering extends from two receivers, established in 1976, to three receivers. The case for four or more receivers was subsequently posed as open problem 5.1 in Network Information Theory.

- C. Nair, "Capacity regions of two new classes of 2-receiver broadcast channels", *IEEE Transactions on Information Theory*, (2010), 4207–4214.
  Summary: This paper establishes capacity of a broadcast channel comprising of a BSC and a BEC and is an early paper that isolates extremal distributions to show collapse of outer

bounds to inner bounds for special settings. This result is covered in Chapter 5 of Network Information Theory.

- † C. Nair, A. El Gamal, and Y-K Chia , "An Achievability Scheme for the Compound Channel with State Noncausally Available at the Encoder", *ArXiv*, (2010), .
  Summary: This paper shows that a straightforward extension of the Gelfand-Pinsker scheme to the compound channel setting is sub-optimal, contrary to two earlier published results claiming so. The capacity region for this setting is posed as open problem 7.2 in Network Information Theory.

- † C. Nair and A. El Gamal, "The Capacity Region of a Class of 3-Receiver Broadcast Channels with Degraded Message Sets", *IEEE Transactions on Information Theory*, (2009), 4479-4493.
  Summary: This paper shows the sub-optimality of superposition coding and Section 8.2 of Network Information Theory is devoted to this result.

- C. Nair and Z. Wang, "On the inner and outer bounds of 3-receiver broadcast channels with 2-degraded message sets", *International Symposium on Information Theory (ISIT)*, (2009), 1844-1848.
  Summary: This paper develops a tailor made argument for a particular channel for which the traditional inner and outer bounds do not agree. It also develops a Mrs. Gerber's like lemma to identify extremal distributions. This lemma will later prove to be an inspiration for a generalization of Mrs. Gerber's lemma.

- † C. Nair and A. El Gamal, "An outer bound to the capacity region of the broadcast channel", *IEEE Transactions on Information Theory*, (2007), 350–355.
  Summary: This paper develops the UV outer bound and shows the strict sub-optimality of the Korner-Marton outer bound. A key contribution is the identification of the binary skew-symmetric broadcast channel as a simple example whose capacity region is unknown. The binary inequality mentioned above was first conjectured for this channel before it was generalized.

Probability and Combinatorial Optimization

- S. Beigi and C. Nair, "Equivalent characterization of reverse Brascamp-Lieb-type inequalities using information measures", *IEEE International Symposium on Information Theory (ISIT)*, (2016), 1038–1042.
  Summary: This paper uses method of types to recast reverse Brascamp-Lieb-type inequalties into equivalent inequalities using relative entropies.

- C. Nair and Y. Wang, "Evaluating hypercontractivity parameters using Information Measures", *IEEE International Symposium on Information Theory (ISIT)*, (2016), 570–574.
  Summary: This paper computes the hypercontractivity region associated with the binary erasure channel. It also gives an alternate proof of the celebrated Bonami's two-point inequality, the hypercontractivity region associated with the binary symmetric channel.

- C. Nair, "Equivalent formulations of Hypercontractivity using Information Measures", *International Zurich Seminar (IZS)*, (2014), .
  Summary: This paper recasts hypercontractive parameters as optimization problems involving information measures. Gohari and Beigi used this characterization to observe that

computing the Gray-Wyner region in network information theory is same as computing the hypercontractivity region for the underlying pair of random variables.

- V. Anantharam, A. Gohari, S. Kamath, and C. Nair, "On Hypercontractivity and a Data Processing Inequality", *IEEE International Symposium on Information Theory (ISIT)*, (2014), 3022–3026.
  Summary: This paper corrects a strong data-processing inequality claimed by Erkip and Cover. By developing the equivalent characterizations linking hypercontractivity, relative entropy, mutual information, and concave envelopes this sets the stage for my further study linking hypercontractivity and network information theory.

- C. Borgs, J. Chayes, S. Mertens, and C. Nair., "Proof of the local REM conjecture for number partitioning I: Constant energy scales", *Random Structures and Algorithms*, (2009), 217–240.
  Summary: This paper establishes a conjecture due to Merten's regarding the Poisson convergence of the ordered energy spectrum corresponding to a number partition problem.

- C. Borgs, J. Chayes, S. Mertens, and C. Nair., "Proof of the local REM conjecture for number partitioning II: Growing energy scales", *Random Structures and Algorithms*, (2009), 241–284.
  Summary: This paper establishes the energy level of the spectrum where the REM conjecture breaks down.

- C. Nair, B. Prabhakar, M. Sharma, "Proofs of the Parisi and Coppersmith-Sorkin random assignment conjectures", *Random Structures and Algorithms*, (2005), 413–444.
  Summary: This paper establishes a long-standing open problem regarding the expected weight of the minimum weighted matching in randomly weighted bipartite graphs. This paper forms the central part of my thesis, though my thesis contains some results not published elsewhere including the closing of a gap in V.S. Dotsenko's argument of the validity of Parisi's conjecture. The conjectures were also simultaneously and independently solved via a different technique by Linusson and Wastlund.

- C. Nair, "Towards the resolution of Coppersmith-Sorkin conjectures", *40th Annual Allerton Conference on Communication, Control and Computing*, (2002), 667–673.
  Summary: This paper presents a set of distributional conjectures on increments between matchings which would imply the previously mentioned conjectures. It was these distributional conjectures that were resolved later providing a proof of the long standing problem. These were motivated by a similar, albeit more restrictive, set of conjectures made by B. Prabhakar and M. Sharma

Network Algorithms

- [†] R. Pan, C. Nair, B. Prabhakar, and B. Yang, "Packet dropping schemes: some examples and analysis", *39th Annual Allerton Conference on Communication, Control and Computing*, (2001), 563–572.
  Summary: This paper does a fluid model based performance analysis of a congestion control mechanism, called CHOKe, for packet buffering.

- [†] A. El Gamal, C. Nair, B. Prabhakar, E. Uysal, and S. Zahedi, "Energy-efficient scheduling of packet transmissions over wireless networks", *IEEE Infocom Conference*, (2002), 1773–1782.
  Summary: This paper presents an iterative algorithm to determine the optimal transmission rates for energy efficient communication in downlink scenarios.

SYNERGISTIC ACTIVITIES (selected)

- Associate Editor - IEEE Transactions on Information Theory. Jan 2014 - Dec. 2016
- TPC co-chair International Symposiums on Information Theory (ISIT) Vail, Colorado - 2018.
- Technical Program Committee member:
  - Information Theory Workshops (ITW): Cairo - 2010, Paraty - October 2011
  - International Symposiums on Information Theory (ISIT): St. Petersburg - 2011, Boston - 2012, Istanbul - 2013, Hawai - 2014, Hong Kong - 2015, Barcelona - 2016, Aachen - 2017
- Reviewer: International Symposium on Information Theory (ISIT), Information Theory Workshop (ITW), Foundations of Computer Science (FOCS), Symposium on Theory of Computation (STOC), IEEE Transactions on Information Theory, IEEE Transactions on Networking, Random Structures and Algorithms, Annals of Applied Probability