Chandra Nair

Dept. of Information Engineering
The Chinese University of Hong Kong
+(852) 3943-8467
chandra@ie.cuhk.edu.hk
http://chandra.ie.cuhk.edu.hk

APPOINTMENTS

Professor, Information Engineering 2019-
Programme Director, Mathematics and Information Engineering (MIEG) 2014-
Associate Professor, Information Engineering 2013-2019
Assistant Professor, Information Engineering 2007-2013
The Chinese University of Hong Kong

- Research interests: Network Information Theory, Information 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

- Wai Ho Ng – PhD 21 "On Gaussian Extremizers for the Capacity Region of the Gaussian Interference Channel" *first job: Post-doc, CUHK*
- Yan Nan Wang – PhD 21 "Optimisation of Some Non-convex Functionals Arising in Information Theory" *first job: Goldman Sachs, Hong Kong*
- Mehdi Yazdanpanah – PhD 19 "Sub-optimality of achievable regions in two fundamental network information theory settings" *first job: Goldman Sachs, Hong Kong*
- Sida Liu – PhD 16 "Genie based outer bounds for interference channels" *first job: BNP Paribas*
- Lingxiao Xia – PhD 16 "On Tightness of Several Achievable Rate Regions in Network Information Theory" *first job: Co-founder and CTO of Portcast*
- Geng Yanlin – PhD 12 "On the Evaluation of Marton's Inner Bound for Binary Input Broadcast Channels" *first job: ShanghaiTech University*
- Zizhou Wang – PhD 10 "On the tightness of inner and outer bounds for broadcast channels with three and more receivers" *first job: ASTRI*

TEACHING

Remark: Graduate classes are marked with a † sign.

- Signals and Systems: 2008, 2009, . . . , 2021, 2022
- Network Information Theory†: 2008, 2011, 2014, 2016, 2019, 2021, 2023

- Theory of Probability†: 2010, 2013, 2015, 2017, 2019, 2022
- Random Processes: 2010†, 2016
- Advanced Engineering Mathematics: 2009
- Basic Circuit Theory: 2007

(INVITED) SEMINARS AND COLLOQUIA (recent, selected)

- New Mathematical Techniques in Information Theory, Oberwolfach, March 2022
- ISIT, Plenary Talk, July 2021
- ETH Zurich, Seminar, January 2020
- Renyi Institute, Workshop, January 2020
- University of Hong Kong, Workshop on Probability and Information Theory, August 2019
- Optimization and Learning Workshop, TIFR, Short Course, January 2019
- ISITA, Plenary Talk, October 2018
- Princeton University, Departmental Seminar, October 2018
- 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

SERVICE (UNIVERSITY)

Major

- Programme Director: Undergraduate programme on Mathematics and Information Engineering (1st August 2014 - present)
  - This is a selective programme aimed to train mathematically mature students ready for graduate study in the theoretical aspects of information sciences. In my role I have to shepherd the program through programme reviews, manage admissions, curriculum, and handle day-to-day affairs of the programme like student counseling and advising. This programme has the highest admission standards in the entire Faculty of Engineering. The programme website is http://www.mie.cuhk.edu.hk
- Institute of Theoretical Computer Science and Communication
  - Associate Director: 1st August 2008 - 31st July 2017, August 2022 - 21st July 2024
  - Director: 1st August 2017 - 31st July, 2019
  - This institute was founded by Prof. Andrew Yao, Turing award winner, in 2007 to foster interdisciplinary research between information and computer sciences. The institute hosts visitors and organizes focussed workshops and schools. The institute also has recently started hosting post-docs who have a flexible mentorship scheme. The institute website is http://www.itcsc.cuhk.edu.hk

Routine (selected)

- Coordinator, Academic Counsel (for students with academic/emotional problems) (Department)
- Advisor, 334 Curriculum Level I Advisors (2013-)
- Member, MAIE/MIEG Programme Committee (Faculty) (2012-2014)
- Member, Selection Panel for Outstanding Thesis Award (Faculty) (2008-2014)
- Member, Task Force on HKIE Outcomes Based Accreditation (Department) (2012-2014)
- Member, Teaching and Learning Committee (Department) (2010-)
- Member, Curriculum Committee (Department) (2009-)
- Member, Executive Committee (Department) current
- Member, Graduate Panel and Research Committee (Department) (2009-2014)

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

- A. El Gamal, A. Gohari, and C. Nair, "A Strengthened Cutset Upper Bound on the Capacity of the Relay Channel and Applications", *IEEE Transactions on Information Theory*, (2022), 5013-5043.
  Summary: We develop a new upper bound on the capacity of the relay channel that is tighter than previously known upper bounds. When specialized to the relay channel with orthogonal receiver components, the bound resolves a conjecture by Kim on a class of deterministic relay channels. When further specialized to the class of product-form relay channels with orthogonal receiver components, the bound resolves a generalized version of Cover's relay channel problem.

- A. Gohari and C. Nair, "Outer Bounds for Multiuser Settings: The Auxiliary Receiver Approach", *IEEE Transactions on Information Theory*, (2022), 701-736.
  Summary: This paper introduces and utilizes a general method of employing auxiliary receivers to fashion outer bounds for network information theoretic settings. Using this idea, it strictly improves on the best known outer bounds for settings in interference, relay, and broadcast channels - the three most fundamental settings in network information theory whose capacity in unknown. Results in the paper include the establishment of a non-zero clope at Costa's corner point for the Gaussian Z-Interference channel and the suboptimality of the cutset outer bound for the scalar Gaussian relay channel.

- C. Nair, "On Marton's Achievable Region: Local Tensorization for Product Channels with a Binary Component", *Information Theory and Applications Workshop (ITA)*, (2020), 1-7.
  Summary: This paper explains the local tensorization concept for information functionals and proves it for the Marton's region for product broadcast channels with a binary component. That local tensorization implies global tensorization for such functionals is a meta-conjecture motivating the results in this paper.

- C. Nair and M. Yazdanpanah, "On the AND-OR Interference Channel and the Sandglass Conjecture", *IEEE International Symposium on Information Theory (ISIT)*, (2020), 1540-1545.
  Summary: This paper establishes an improved upper bound on the rate-sum of the AND-OR interference channel, and disproves the conjectured optimality of the time-division strategy. For the zero-error case of this problem, also known as the Sand Glass conjecture, this outer bound is also an improvement of the previously best known one.

- V. Anantharam, A. Gohari, and C. Nair , "On the evaluation of Marton's inner bound for two-receiver broadcast channels", *IEEE Transactions on Information Theory*, (2019), 1361-1371.
  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. This improved bound makes numerical evaluation of two-letter region possible for small input alphabets, and simulations have not yielded counterexamples to the optimality of Marton's bound so far.

- C. Nair, and D. Ng, "Invariance of the Han-Kobayashi region with respect to temporally-correlated Gaussian inputs", *IEEE Transactions on Information Theory*, (2019), 1372-1374.
  Summary: This paper establishes that multi-letter extensions of Gaussian signaling does not improve on the single-letter scheme.

- 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.

- 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 and L. Xia, "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.

Information Inequalities, Probability, and Combinatorial Optimization

- K. Lau, C. Nair and D. Ng, "A mutual information inequality and some applications", *IEEE International Symposium on Information Theory (ISIT)*, (2022), 951-956.
  Summary: We show that a 2-point mutual information inequality can be used to derive results a general as fractional super-additivity of entropy powers.

- K. Lau, C. Nair and C. Yao, "Uniqueness of local maximizers for some non-convex log-determinant optimization problems using information theory", *IEEE International Symposium on Information Theory (ISIT)*, (2022), 432-437.
  Summary: For information functionals whose Gaussian optimality can be deduced by strict sub-additivity and rotation trick, we show how the proof technique also implies the uniqueness of local maximizers in the Gaussian space. We demonstrate this in the context of Gaussian broadcast channels and in the case of Brascamp-Lieb inequalities. Further the technique also identifies local directions where the function is increasing.

- V. Anantharam, V. Jog and C. Nair, "Unifying the Brascamp-Lieb Inequality and the Entropy Power Inequality", *IEEE Transactions on Information Theory*, (2022), 7665-7684.
  Summary: A sub-additivity result is established that is then used to prove a general family of inequalities that includes Brascamp-Lieb as one extreme and the Entropy Power Inequality as the other extreme. The optimality of Gaussian distributions is established using the trick introduced in Geng and Nair (2014); and for those researchers not interested in network information theory, this article provides a self-contained introduction to this technique of establishing Gaussian optimizers.

- 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:
  - International Symposium on Information Theory (ISIT): St. Petersburg - 2011, Boston - 2012, Istanbul - 2013, Hawai - 2014, Hong Kong - 2015, Barcelona - 2016, Aachen - 2017, Paris - 2019
  - Information Theory Workshops (ITW): Cairo - 2010, Paraty - October 2011