Mathematical Coding Theory in Multimedia Streaming
October 11 – 16. 2015

MEALS

*Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday
*Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday
*Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday
Coffee Breaks: As per daily schedule, in the foyer of the TransCanada Pipeline Pavilion (TCPL)
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in the lecture theater in the TransCanada Pipelines Pavilion (TCPL). An LCD projector, a laptop, a document camera, and blackboards are available for presentations.

SCHEDULE

The schedule may slightly change as the workshop proceeds. Information will be provided in a timely manner.

Sunday

16:00	Check-in begins (Front Desk - Professional Development Centre - open 24 hours)
17:30–19:30	Buffet Dinner, Sally Borden Building
20:00	Informal gathering in 2nd floor lounge, Corbett Hall (if desired) Beverages and a small assortment of snacks are available on a cash honor system.

Monday

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, TCPL
9:00–9:15	Introduction and Welcome by the Organizers, Emina, TCPL
9:15–10:15	Roxana Smarandache: Convolutional Codes
10:15–10:45	Coffee Break, TCPL
10:45–11:45	Ashish Khisti: Streaming Codes for Channels with Burst and Isolated Erasures
11:45–13:00	Lunch
13:00–14:00	Break for discussion
14:00–15:00	20 presentation @ 3-minutes
15:00–15:30	Coffee Break, TCPL
15:30–16:30	20 presentation @ 3-minutes
16:30–17:30	Forming working groups
17:30–19:30	Dinner

Tuesday

7:00–9:00	Breakfast
9:00–10:00	Gauri Joshi: Throughput-Smoothness Trade-offs in Streaming Communication
10:00–10:30	Coffee Break, TCPL
10:30–11:30	Dan Costello: Spatially Coupled LDPC Codes: From Theory to Practice
11:30–13:30	Lunch

13:30–14:30	Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
14:30–14:45	Group Photo; meet in foyer of TCPL (photograph will be taken outdoors so a jacket might be required).
14:45–15:15	Coffee Break, TCPL
15:15–17:00	Group activities
18:00–19:30	Dinner

Wednesday

7:00–9:00	Breakfast
9:00–9:30	Ankit Singh Rawat: Dynamic Control of Video Quality in Adaptive Video Streaming
9:30–10:00	Yuval Cassuto: Low-Delay Codes Minimizing the Average Delay Among Lost Packets
10:00–10:30	Coffee Break, TCPL
10:30–11:30	Raptor Codes: From a Math Idea to LTE eMBMS
11:30–13:30	Lunch
	Free Afternoon recommended
17:30–19:30	Dinner

Thursday

7:00–9:00	Breakfast
9:00–10:00	Elisa Gorla: Rank distribution of Delsarte codes
10:00–10:30	Coffee Break, TCPL
10:30–11:00	Margreta Kuijper: Linear systems under adversarial attack— an error control perspective
11:00–11:30	Martin Bossert: Error Correction for Physical Unclonable Functions
11:30–13:30	Lunch
13:30–14:30	Group activities
14:30–15:00	Coffee Break, TCPL
15:30–16:00	Diego Napp: MDP Convolutional Codes
16:00–16:30	Alex Sprintson: Cooperative Data Exchange with Deadlines
16:30–17:30	Group activities
17:30–19:30	Dinner

Friday

7:00–9:00	Breakfast
9:00 –10:00	Working group reports
10:00–10:30	Coffee Break, TCPL
10:30–11:30	Informal discussions about funding opportunities
11:30–13:30	Lunch

Checkout by 12 noon.

** 5-day workshop participants are welcome to use BIRS facilities (BIRS Coffee Lounge, TCPL and Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

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ABSTRACTS
(in alphabetic order by speaker surname)

Speaker: **Martin Bossert** (University of Ulm (Germany))
Title: *Error Correction for Physical Unclonable Functions*
Abstract: Physical Unclonable Functions (PUFs) evaluate manufacturing variations to generate secure cryptographic keys for embedded systems. These keys can be reproduced on demand, thus, the key has not to be stored. However, due to aging and temperature variation the output of a PUF varies and therefore channel coding has to be used in order to ensure reliable key reproduction. The mathematical models and methods for key generation with PUFs are explained.

Speaker: **Yuval Cassuto** (Technion (Israel))
Title: *Low-Delay Codes Minimizing the Average Delay Among Lost Packets*
Abstract: Low-delay recovery from erasure bursts is an important feature for many time-sensitive communication applications. The delay is measured as the time (in unit of packets) between the transmission of the (lost) packet, until it is fully decoded at the receiver. When all packets are required to have the same delay, an optimal coding scheme was given by Martinian et. al in 2004. In this work we observe that if we lift the constant-delay requirement, the average delay across all lost packets can be *significantly* reduced, and still exhibit optimality. This case is motivated by emerging applications in distributed control, e.g., automotive communications.

Speaker: **Dan Costello** (University of Notre Dame)
Title: *Spatially Coupled LDPC Codes: From Theory to Practice*
Abstract: Following a short review of the basic concepts of low-density parity-check (LDPC) codes, we summarize both the theoretical and practical aspects of spatially coupled LDPC codes from several different perspectives. First, using protograph-based code ensembles, the asymptotic ensemble average properties of spatially coupled LDPC codes are presented, including both iterative decoding thresholds and minimum distance growth rates. Next, finite-length code properties, such as bit-error-rate (BER) performance, decoding latency, and decoding complexity are presented. With sliding window decoding, we see that spatially coupled LDPC codes achieve a BER performance advantage compared to LDPC block codes for fixed decoding latency and practical block (window) sizes, and decoding complexity comparisons are presented for both binary and non-binary codes. Finally, the BER performance advantages of spatially coupled LDPC codes are shown to also hold when puncturing is employed to achieve higher code rates.

Speaker: **Elisa Gorla** (University of Neuchatel (Switzerland))
Title: *Rank distribution of Delsarte codes*
Abstract: In his famous work on bilinear forms over finite fields, Delsarte established a rank-distance analogue of the Singleton bound. Codes which achieve the bound are called MRD, and they are the analogue for the rank-distance of MDS codes for the Hamming distance. Delsarte showed that the rank distribution of an MRD code is determined by its parameters. Building on the work of Delsarte, in this talk I will define a notion of rank defect for rank-metric codes, analogous to the Singleton defect for classical codes. Rank defect, generalized rank-weights, MacWillliams identities, and dual codes all play a role in studying rank distributions, and I will discuss these connections. In particular I will show that the rank distribution of codes whose rank defect and dual rank defect are both zero is determined by their parameters. This recovers and generalizes the result of Delsarte on the weight distribution of MRD codes. In the general case, I will show that the rank distribution is determined by the parameters of the code,

together the number of codewords of small rank. *(The new results which I will present in this talk are joint work with J. De la Cruz, H. Lopez, A. Ravagnani.)*

Speaker: **Gauri Joshi** (MIT)
Title: *Throughput-Smoothness Trade-offs in Streaming Communication*
Abstract: Unlike traditional file transfer where only total delay matters, streaming applications impose delay constraints on each packet and require them to be in order. To achieve fast in-order packet decoding, we have to compromise on the throughput. We study this trade-off between throughput and smoothness in packet decoding.

We first consider a point-to-point streaming and analyze how the trade-off is affected by the frequency of block-wise feedback, whereby the source receives full channel state feedback at periodic intervals. Then we consider the problem of multicasting a packet stream to two users. For both point-to-point and multicast streaming, we propose a spectrum of coding schemes that span different throughput-smoothness tradeoffs. One can choose an appropriate coding scheme from these, depending upon the delay-sensitivity and bandwidth limitations of the application.

Speaker: **Ashish Khisti** (University of Toronto)
Title: *Streaming Codes for Channels with Burst and Isolated Erasures*
Abstract: An increasing number of applications are streaming in nature. Information packets must be encoded and transmitted sequentially in real-time, and the receiver should reproduce the source stream under strict delay constraints. In such systems the study of fundamental (information-theoretic) limits as well as the associated coding schemes remains a fertile area of research. In this talk I will (i) present the operational significance of column-distance and column-span in streaming systems, (ii) exhibit a fundamental tradeoff between these metrics, and (iii) propose a class of convolutional codes that achieve a near-optimal tradeoff. Some multiuser extensions of the streaming setup will also be discussed.

Speaker: **Margreta Kuijper** (University of Melbourne (Australia))
Title: *Linear systems under adversarial attack— an error control coding perspective*
Abstract: We look at linear time-invariant multi-output systems that are vulnerable to attacks. More specifically, an unknown number of outputs is vulnerable to adversarial attacks that take place over time. Typical problem statements in this area are: how many outputs need to be minimally attacked in order for the attack to be undetectable? Also: suppose the attacks affect M outputs—what is the maximum value of M that guarantees the possibility of attack correction? These types of questions are inviting to a coding theorist' eye. In this talk we take up the invitation and introduce the notion of a "security index" of the system. We cement the link with coding theory and also look at feedback control systems. We reflect on the importance of the feedback control system's security index in terms of control objectives. *(Joint work with Michelle Chong).*

Speaker: **Ankit Singh Rawat** (Carnegie Mellon University)
Title: *Dynamic Control of Video Quality in Adaptive Video Streaming (AVS)*
Abstract: Adaptive video streaming (AVS) aims to ensure high quality of experience (QoE) delivery of video content to a user under the conditions of time varying bandwidth between video server and the user. In the Adaptive Video Streaming (AVS), a server stores multiple video quality versions for each chunk in a video file, and a client takes the decision about which chunk quality to download in order to adapt to changing channel conditions. In this talk, Ill introduce the basic set up of AVS. Ill then talk about a simple and effective algorithm for video quality selection and buffer control, which is based only on the current state of the client's playback buffer. Ill also discuss the performance of the algorithm regarding three important QoE measures and the tradeoff between them: 1) likelihood of play-out interruptions and video packet loss, 2) fraction of video watched in high quality, and 3) amount of fluctuations in video quality. *(Joint work with Emina Soljanin)*

Speaker: **Alex Sprintson** (Texas A&M University)
Title: *Cooperative Data Exchange with Deadlines*
Abstract: We consider the cooperative data exchange problem with hard deadlines on the packet delivery. We focus on a setting in which each client holds a random set of packets and needs to recover all packets held by other clients. The clients exchange coded packets over a noiseless broadcast channel. Our goal is to construct a transmission schedule and the coding scheme that maximize the number of clients that can decode all the packets they need before the deadline. This problem has several interesting practical applications in vehicular and aerial networks. We show that it is possible to construct a closed form solution to this problem which is feasible and optimal with high probability. Our proof techniques use linear programming techniques with cut-set constraints and the concentration bounds. While our optimality results so far are asymptotic in the number of packets, we are currently exploring ways to achieve a better convergence. Initial simulation results indicate that our algorithm performs well in practical settings. *(Joint work with A. Heidarzadeh and M. Yan)*