



## Workshop White Paper

### *Position Paper*

Marie-José Montpetit and Muriel Médard  
Research Laboratory of Electronics  
Massachusetts Institute of Technology  
{mariejo,medard@mit.edu}

### **Purpose**

As content consumption is moving to the multi-screen and device ecosystem of the new Internet landscape, novel challenges are emerging. Deploying any content-centric solutions now requires multidisciplinary approaches for both the networks that will support the services as well as of the capabilities of the different devices that will render the experience. For example, traditional television delivery systems are based on content being acquired and distributed to a single end device under the control of a single operator. As video has moved onto the Internet and to wireless networks, this model is now obsolete: TV content is nowadays available from a variety of networks and operators and rendered via web technology on any device capable of supporting a browser. With the convergence of voice, text, video and gaming, ancillary content and extra features are combined to the main streams and can be inserted anywhere in the delivery chain. In just a few years video delivery has gone from a linear value chain to a multidimensional one with growing complexity. This increase in quantity and complexity of demand for entertainment services is combined with the scarcity of wireless resources and the growing energy use of networks in storing and conveying media, leads naturally to having content shared locally without wasting bottleneck resources for digital rights management, retransmission of lost segments, long-distance transmission of data that is locally available, and other non-revenue generating traffic.

This workshop intends to present current projects from our team and our sponsors and define strategies to produce, deliver and consume video better on the inter-net and inter-cloud of the near future. We want to address aspects from generation to

rendering and social viewing in a way that is cross-disciplinary and end-to-end in the network. The presented work builds on recent research on network coding and social viewing highlighted in MIT News and the MIT splash page several times in last couple of years and the MIT Technology Review TR10. Of particular interest are the aspects of our research that address new mechanisms, beyond traditional client-server architectures, such as: network coded peer to peer and distributed storage; quality of experience (QoE) with device augmentation through network combining and layered content protection that socializes content and in particular video viewing. We strongly believe that sharing research and ideas within the workshop community and getting the feedback of the participants will be beneficial to all.

### **Our Group**

Our group is composed of about 20 students and researchers. Our projects cover a wide spectrum of topics from traditional information theory to network coding and technologies from optical devices



to base station to home networks. One focus of the workshop will be on Network coding (NC) that allows us to reconsider the way content is handled over a variety of network.

NC considers data as algebraic entities not just sets of bits. As such it assumes that digital traffic can be combined by addition and multiplication by other entities. While NC has been the topic of research in the last 10 years it is now receiving a lot of attention in the technology world as one enabler of the *Internet of Information Nodes*. In particular, since network codes do not need to be end to end, NC allows tailoring coding strategies to the dynamics and topology of the network and to the features of the receiver ecosystem. This is very beneficial when transporting any content but especially video traffic over heterogeneous networks to a variety of end devices. Network coding provides the fundamental research over which some of the workshop presentation will be based on.

## Workshop Background

Content *production* will be addressed from a number of different directions. E-Books, YouTube, Facebook, Over The Top content have multiplied the choices for content consumption and commenting in the past few years. As more and more content has migrated to the Internet, “personal” content has been becoming the norm. The immediacy and social aspects of content consumption of every kind, and of video in particular, are being integrated into better experiences. With Internet content, multiple delivery mechanisms and personalization, the applications “sandbox” is

expanding fast. The impact of Internet content to the home and of community networks on the landscape of video distribution and content consumption, is still difficult to evaluate but there is obviously no turning back. TV content in particular is being impacted by social viewing expectations, which reconnect with and go beyond a type of experience that reaches back to TV’s original social roots. The workshop wants to present some facets of the new social content experience from video technology fundamentals and challenges, to user interfaces. It is also important to note that other potential strategies to improve video distribution that use the layered nature of video codecs will also be presented.

Connectivity is essential to social consumption of content. The old model based on total operator control from content formatting, advertisement serving and rendering is being challenged by over the top (OTT), user generated content, co-viewing and mobile services. The result of this disintermediation is that any content consumption experience will be influenced by the networks and platforms that support it with appropriate quality of experience. Basic performance metrics, especially in the mobile world, require new approaches to caching and transmissions. In this environment, NC allows to modify and/or store content in the network nodes, without tight controls, and to add protection only where needed, thus freeing resources, and enabling peer-to-peer distribution with local features, such as advertisement. In particular, interest in peer-to-peer distribution over small community networks sometimes termed the “anti-cloud”, is growing with the needs for greener networking and targeted and personalized services. With network coded video, there is no need to know exactly where a piece of video is located: to regenerate a file there is only a need to gather “useful” combinations of content until there are enough degrees of freedom accumulated to allow decoding. These inputs can come from local as well as from remote locations and be combined with ancillary information when needed without added complexity. Hence there is a small trade-off between, on the one hand, using a complex stateful implementation and, on the other hand, some added acquisition and decoding delay. But there are other ways to further reduce the delays. This is by “borrowing” resources from another network or from another path, in essence

improving one network by using another. Our work has shown that file downloads durations can be greatly reduced by using a 4G network to “help” a WIFI network in times of high demands. Again, the relaxation of the tight controls on content location enables this to happen. This creates the core of the *dissemination* section of the workshop.



But producing and getting the information to its destination with added social commentary and filtering, are not sufficient for creating the content experience of the future: content and privacy need to be protected. We are investigating novel approaches to content protection in a social viewing perspective. Heavily encrypted approaches fail to meet the needs of both commercially produced content that needs protection when this content is shared amongst devices and “friends” and gets annotated and enhanced. One aspect of Network Coding that is yet to be fully exploited is how its algebraic structure inherently protects the encoded content. We

propose an approach for distributed content verification without the need to contact a trusted authority. Our techniques build upon our earlier work on constructing homomorphic signatures. In addition, since the encryption of the NC coefficients is very lightweight, the decoding time is very short and significantly faster than traditional decryption. Finally, in a peer-to-peer distribution networks, while peers can help to disseminate NC video content, they will not be able to decode it without the right signature information. The W3C has been recently interested by these approaches that enable content protection outside the current Digital Rights Management, that are heavily dependent on business models and licensing. Our approach may enable new dissemination and consumption paradigms to be deployed.

## Selected Bibliography

- [1] MIT News, “The Power of Random”, <http://web.mit.edu/newsoffice/2010/network-coding-part1.html>
- [2] MIT New, “Rethinking Networking”, <http://web.mit.edu/newsoffice/2010/network-coding-part2.html>
- [3] MIT Technology Review, “TR10”, May-June 2010, <http://www.technologyreview.com/communications/25084/?a=f>
- [4] R. Koetter and M. Médard, “An algebraic approach to network coding,” *IEEE/ACM Trans. Networking*, vol. 11, no. 5, pp. 782–795, Oct. 2003.
- [5] M. Kim, Lima, L., Zhao, F., Barros, J, Médard, M., Koetter, R., Kalker, T. and Han, K., “On Counteracting Byzantine Attacks in Network Coded Peer-to-Peer Networks”, *IEEE Journal on Selected Areas in Communications: Special Issue on Mission-Critical Infrastructure*, vol 28, Issue 5, May 2010, pp. 692-702.
- [6] P. F. Oliveira, L. Lima, T. T. V. Vinhoza, M. Médard, J. Barros, “Trusted Storage over Untrusted Networks.”, *Globecom 2010*.
- [7] M.J. Montpetit, “Community Networking: Getting Peer to Peer out of Prison”, *Communications Futures Program Winter Plenary*, January 18 2008, [cfp.mit.edu](http://cfp.mit.edu).
- [8] M.-J. Montpetit and Médard, M., “[Video-centric Network Coding Strategies for 4G Wireless Networks: An Overview](#)”, *2010 IEEE Consumer Communications and Networking Conference*.
- [9] A. ParandehGheibi, M. Médard, A. Ozdaglar, S. Shakkottai, “[Avoiding Interruptions — A QoS Reliability Function for Streaming Media Applications](#)”, *IEEE Journal on Selected Areas in Communications*, vol. 9, issue 5, May 2011, pp 1064 – 1074.
- [10] J. K. Sundararajan, Shah, D., Médard, M., Jakubczak, S., Mitzenmacher, M. and Barros, J., “[Network Coding Meets TCP: Theory and Implementation](#)”, *Proceedings of the IEEE*, March 2011, pp. 490 – 512.
- [11] M.J. Montpetit. T. Mirlacher and N. Klym, “The Future of TV: Mobile, IP-based and Social”, *Springer Journal of Multimedia Tools and Applications*, Spring 2010.
- [12] M.J. Montpetit and M. Médard, “Community Viewing meets Network Coding: New Strategies for Distribution, Consumption and Protection of TV Content.”, *Second W3C Workshop on Web and TV*, Berlin, February 2011.
- [13] A. Kulkarni, M. Heindlmaier, D. Traskov, M. Médard, and M.J. Montpetit, “Network Coding with Association Policies in Heterogeneous Networks.” *NC-Pro Workshop*, May 2011.