Network Coding Research Group (NWCRG) Overview

IAB Review
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Network Coding

• Network coding is a method of optimizing the flow of digital data in a network by transmitting digital evidence about messages ...

• Potential benefits for
  – Capacity
  – Robustness
  – Security
  – Energy efficiency
Motivation for NWCRG

• Research proved performance gains and practical algorithms
  – From: Netcoding multicast achieves max flow-min cut
  – To: Coding scheme for reliable communication over packet networks
  – To: results in capacity of wireless networks using network coding
  – And many others
  – Much research remains to be done.

• Mature Implementations
  – Full network coding systems have been demonstrated
  – Network coding has begun “popping up” in various IRTF, IETF, and other forums
  – More general applicability and opportunity seen with new paradigms such as Information Centric Networking and Software Defined Networking
Open Research Areas

- Aspects of packet network systems
  - Control, Routing / forwarding, Transport, Physical layers
- How can network coding be effectively and pragmatically applied to a scalable, distributed network like the Internet?
  - Congestion control, End vs. Intermediate System, Edge (wireless)
- Where does network coding provide benefit?
- Architecture, operation and applications
  - End-to-end vs. hop-by-hop
  - Intra-flow and inter-flow
  - Application-layer use
  - Service paradigms: Best Effort, Content, Multimedia
Candidate Areas for standardization (longer term)

• Common encoding algorithms
• Protocols:
  – Network Coding Transport
  – Routing: subgraph construction
  – Forwarding on subgraphs
• Service descriptions
• Packet formats
Current Activities and Approach

• Information exchange
  – Coding techniques
  – Protocol concepts
  – Use cases

• Taxonomy and architecture development
  – Attempting to derive a building block approach from key use cases and identifiable functional areas
Building Blocks

Prior Example: RMT Building Block Approach

Applications

Protocol Instantiations

* Unrealized building blocks
Network Coding System Decomposition

System

Functional Area 1
  - Building Block

Functional Area 2
  - Building Block

Functional Area ‘N’
  - Building Block
Network Coding Use Cases

1. NC shim* layer - under TCP, UDP, SSH
2. NC transport, in-network coding
3. NC transport over overlay network
4. NC shim* under tunnel (MPLS, IPsec)
5. Coded TCP (or TCP-like) over disjoint paths
6. NC content dissemination at application layer

(*) Shim: usually between routing and transport

Note: This is not an exhaustive list, but hopefully a large enough set to help identify key building blocks that can be reapplied for different use cases.
Use Case 2: NC Transport, In-Network Coding

- Assisted by multi-path (subgraph) routing
- Usage: reliability, resilience to link and node outage.
- Supports both Unicast and Multicast
Network Coding Functional Areas

• NC Coding
  – All coding operations
• NC Reliability
  – Data and control to support reliable transfer
• NC Congestion Control
  – Controls transmission rates
  – Try to use existing algorithms
• Multi-path routing, multi-path forwarding
  – How network coding is distributed over network from source(s) to destination(s)
• Security
  – First option: rely on existing solutions
  – Coding can be used for pollution detection and correction, anonymization, protection against denial of service
Network Coding RG Activities

- Chartered on 2013-11-13
- ~28 research presentations over 4 meetings
- Network Coding Taxonomy, now an RG draft
  draft-irtf-nwcrg-network-coding-taxonomy-00
- Individual drafts
  draft-amdouni-nwcrg-cisew-00
  draft-detchart-nwcrg-tetrys-00
  draft-khasnabish-nwcrg-impact-of-vir-and-sdn-02
- Proposal for a Network Coding Architecture
- Planned: Network Coding Tutorial draft
Issues and Mitigation

• IPR: Some aspects (coding, etc) have IPR claims
  – Reminders and follow-ups to file disclosures
  – Architecture open to full range of algos

• Need for interaction with other IRTF research groups and/or IETF working groups
  – Build stronger awareness, participation within NWCRG

• Current emphasis on end-to-end transport
  – Encourage consideration of richer network coding approaches
Backup
NWCRG Motivation: Research Advances

Research proved performance gains and practical algorithms

- Ahlswerde et al, 2000
  - Network coded multicast achieves max flow-min cut
- S Li et al 2003
  - Linear coding w/ finite symbol size- sufficient for multicast
- Koetter, Medard 2003
  - Algebraic framework for linear network-coding
  - Min-cut max-flow achieved w time-invariant solutions for networks with delay and cycles.
- Ho et al 2003
  - Distributed randomized network coding
- Lun et al 2005
  - coding scheme for reliable transport over packet networks
- And many others. Much research remains to be done.
Use Case 1: NC Shim Layer – under TCP, UDP, SSH

- Coding: end-end. Passes CC signaling.
- Optional: in-network re-coding.
- Coding nodes determined by: static configuration, routing or control signaling.
- Usage: reliability, similar to source coding.
Use Case 3: NC Transport over Overlay Network

- Overlay links can be reliable (TCP) or unreliable (UDP).
- Requires both reliability and congestion control functions
- Usage: reliability, resilience to link and node outage, anonymity.
Use Case 4: NC Shim under Tunnel (MPLS, IPsec)

- Usage: Provides reliable forwarding under MPLS tunnel
- Assumes configured IP tunnels or routes under NC shim
Use Case 5: Coded TCP (or TCP-like) over Disjoint Paths

- Coding: over all paths
- Congestion control: separate for each path