Network Coding Research Group (NWCRG) Overview

IAB Review

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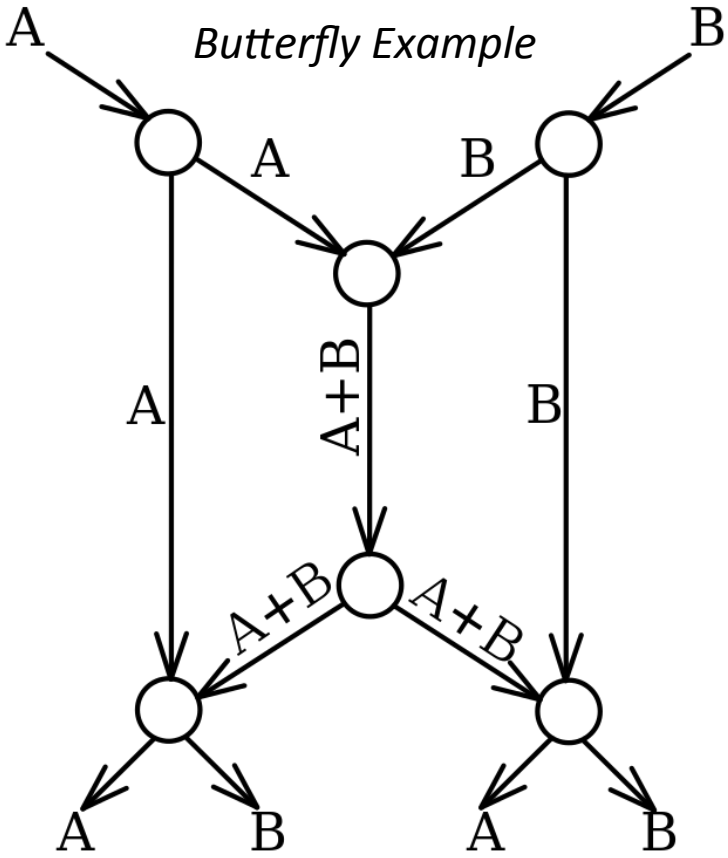
Network Coding

- 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

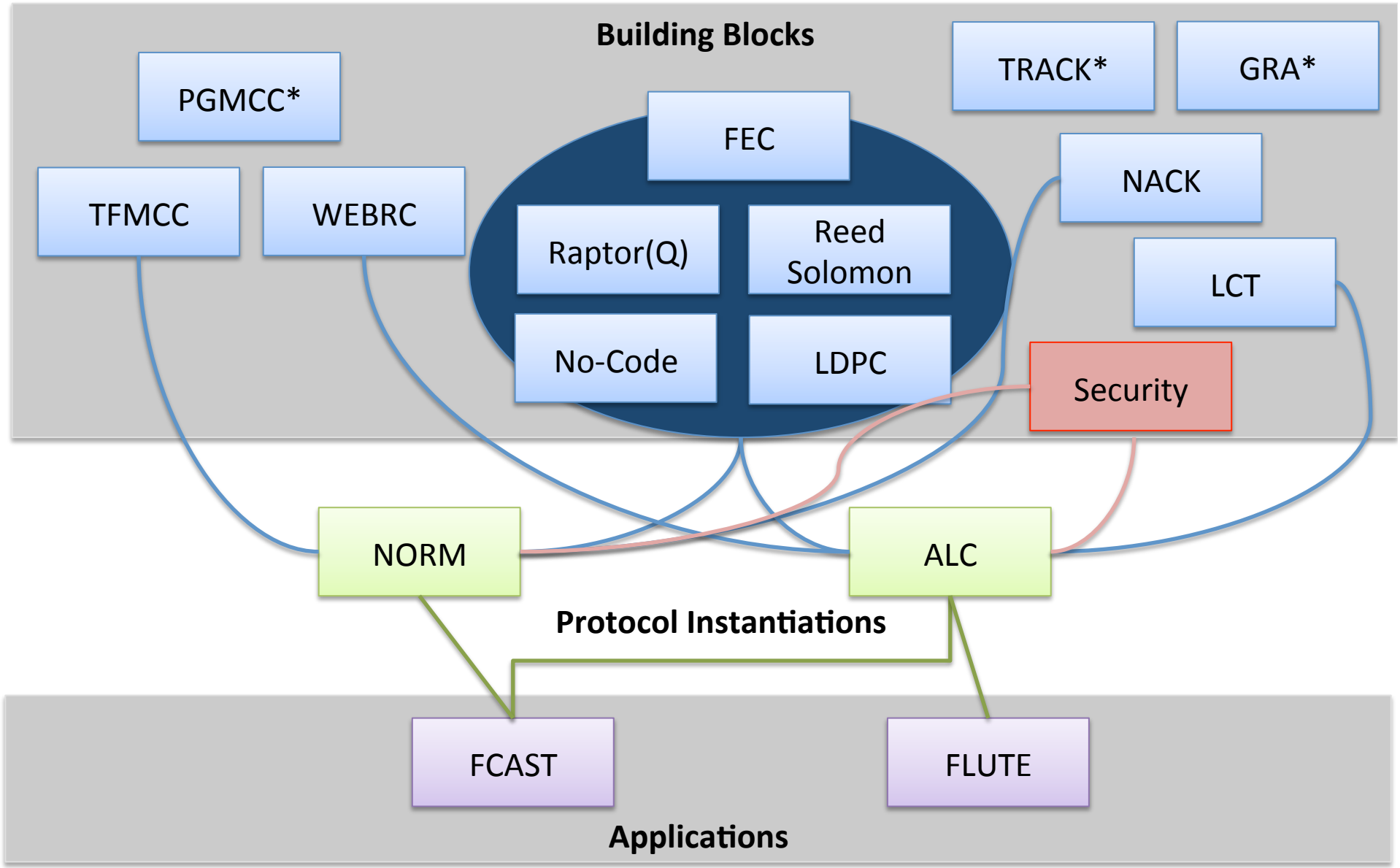
Candidate Areas for standardization (longer term)

- Common encoding algorithms
- Protocols:
  - Network Coding Transport
  - Routing: subgraph construction
  - Forwarding on subgraphs
- Service descriptions
- Packet formats

Current Activities and Approach

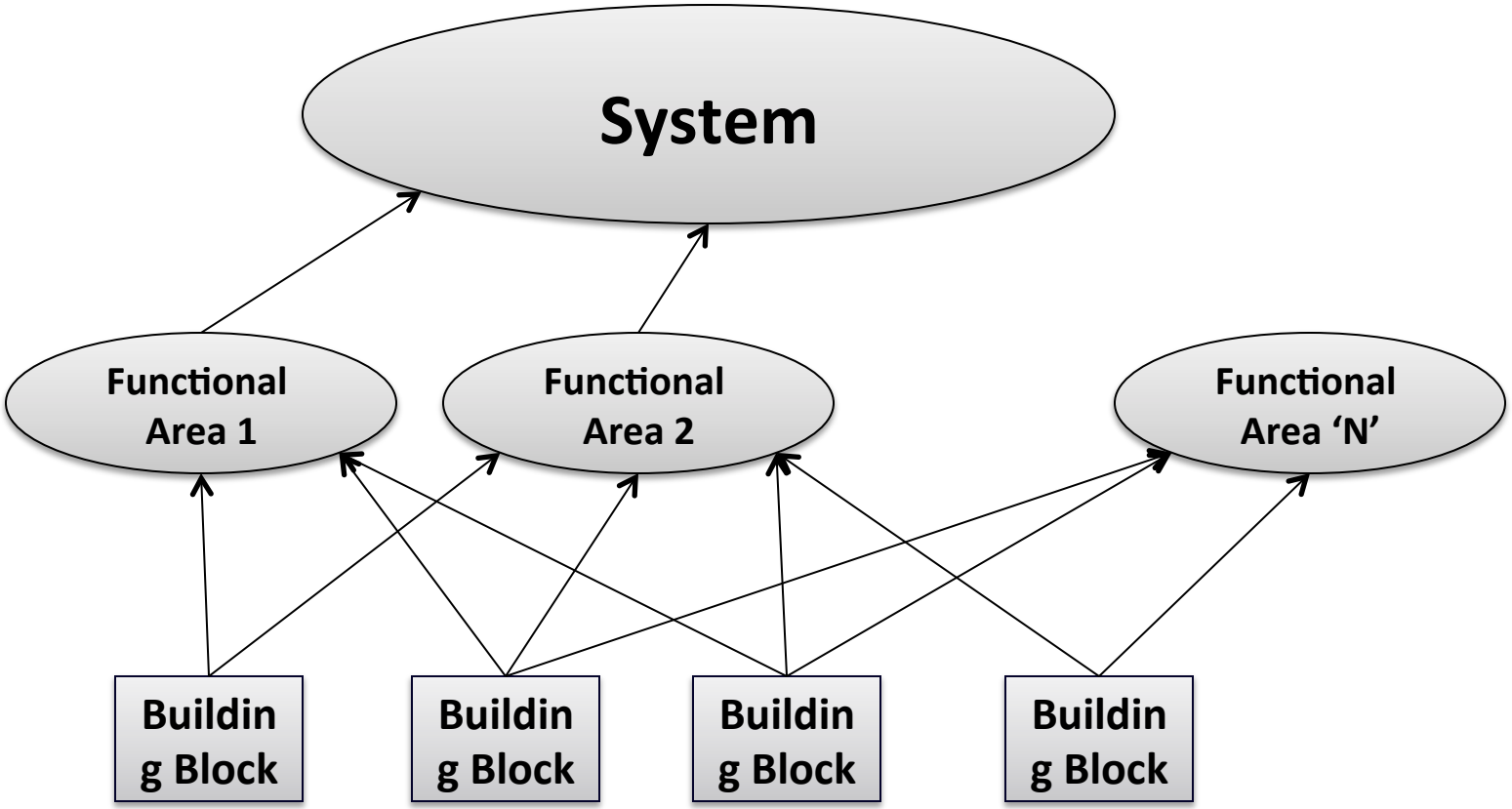
- Information exchange
  - Coding techniques
  - Protocol concepts
  - Use cases
- Taxonomy and architecture development
  - Attempting to derive a building block approach from key use cases and identifiable functional areas

Prior Example: RMT Building Block Approach



** Unrealized building blocks*

Network Coding System Decomposition



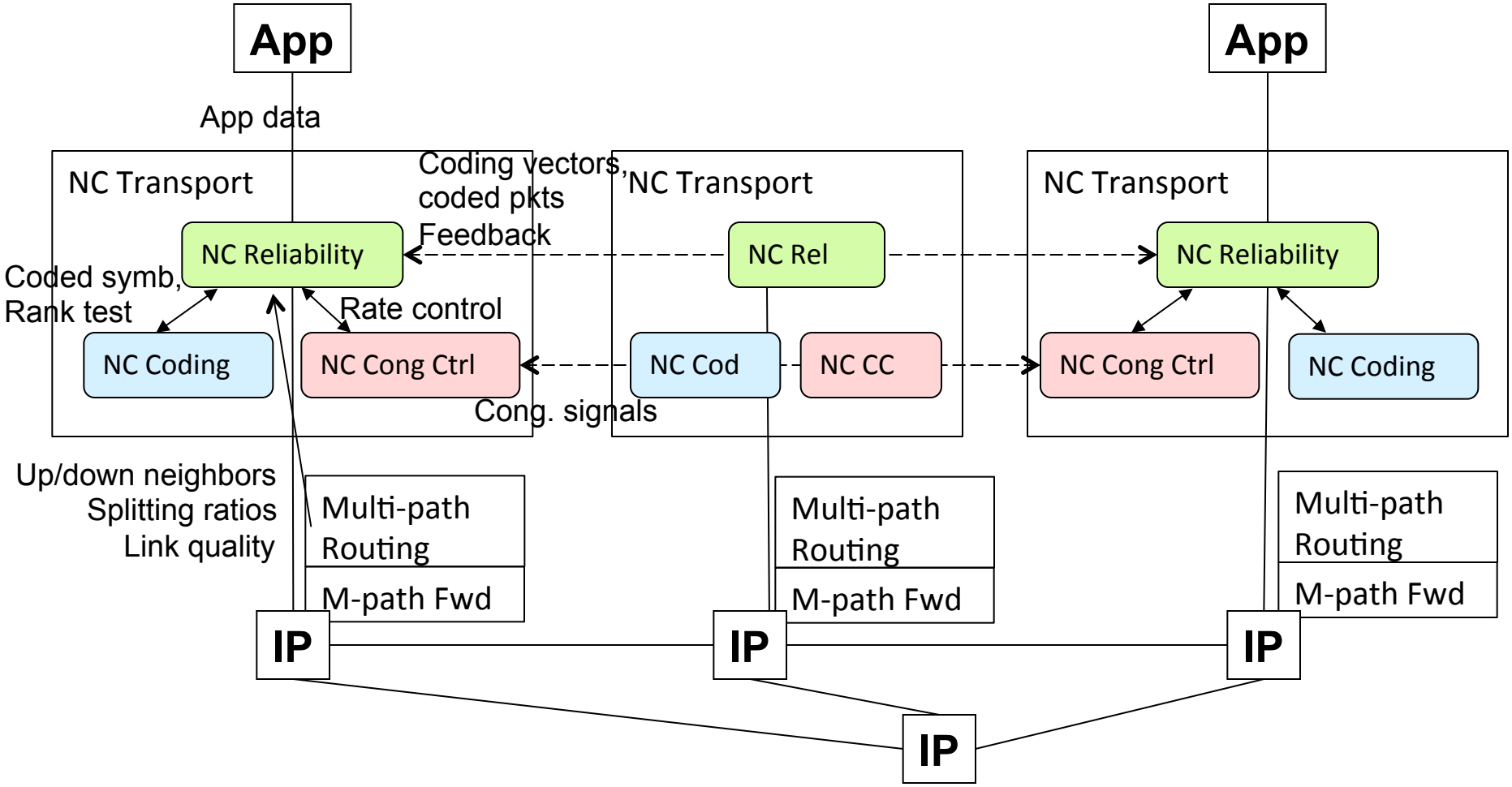
Network Coding Use Cases

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, anonimization, 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

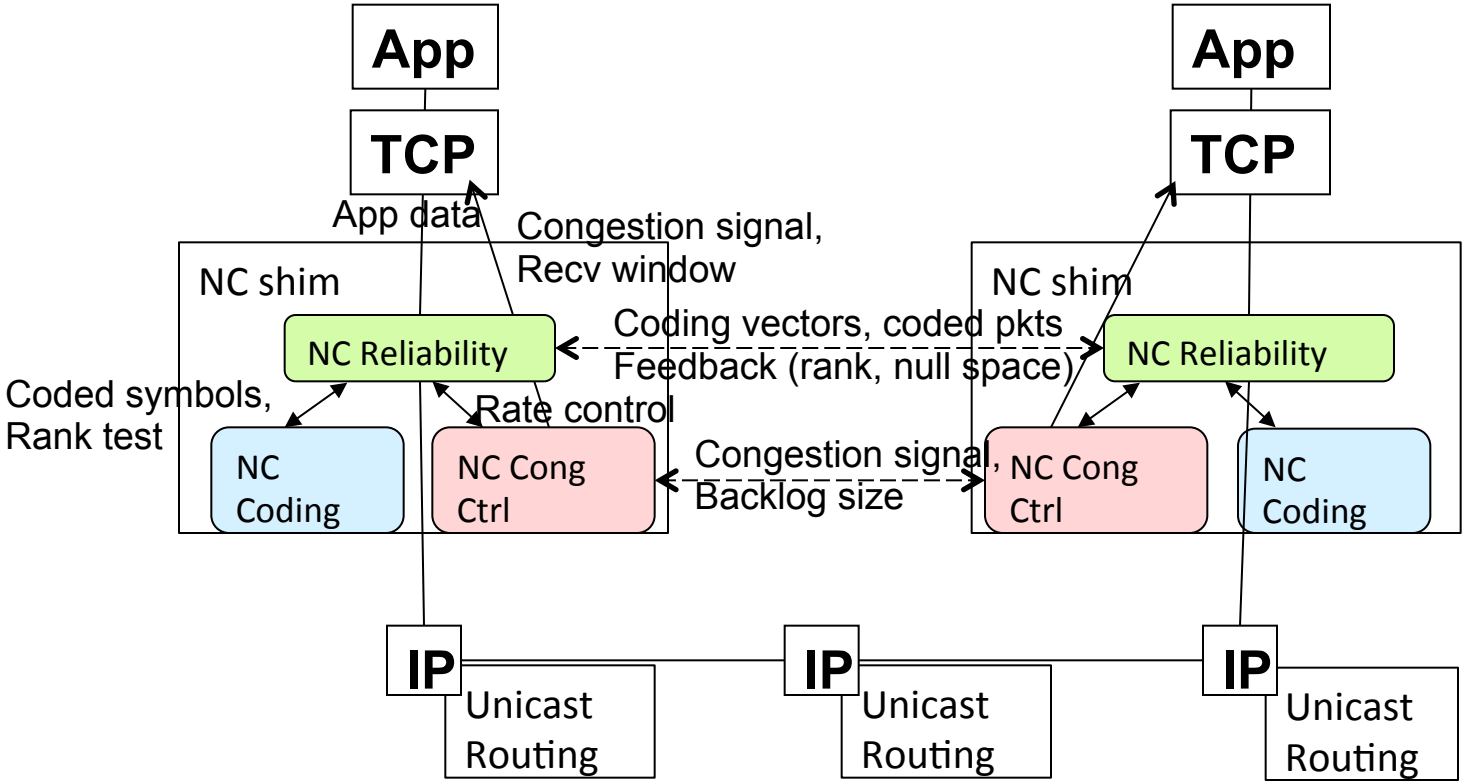
Backup

NWCRG Motivation: Research Advances

Research proved performance gains and practical algorithms

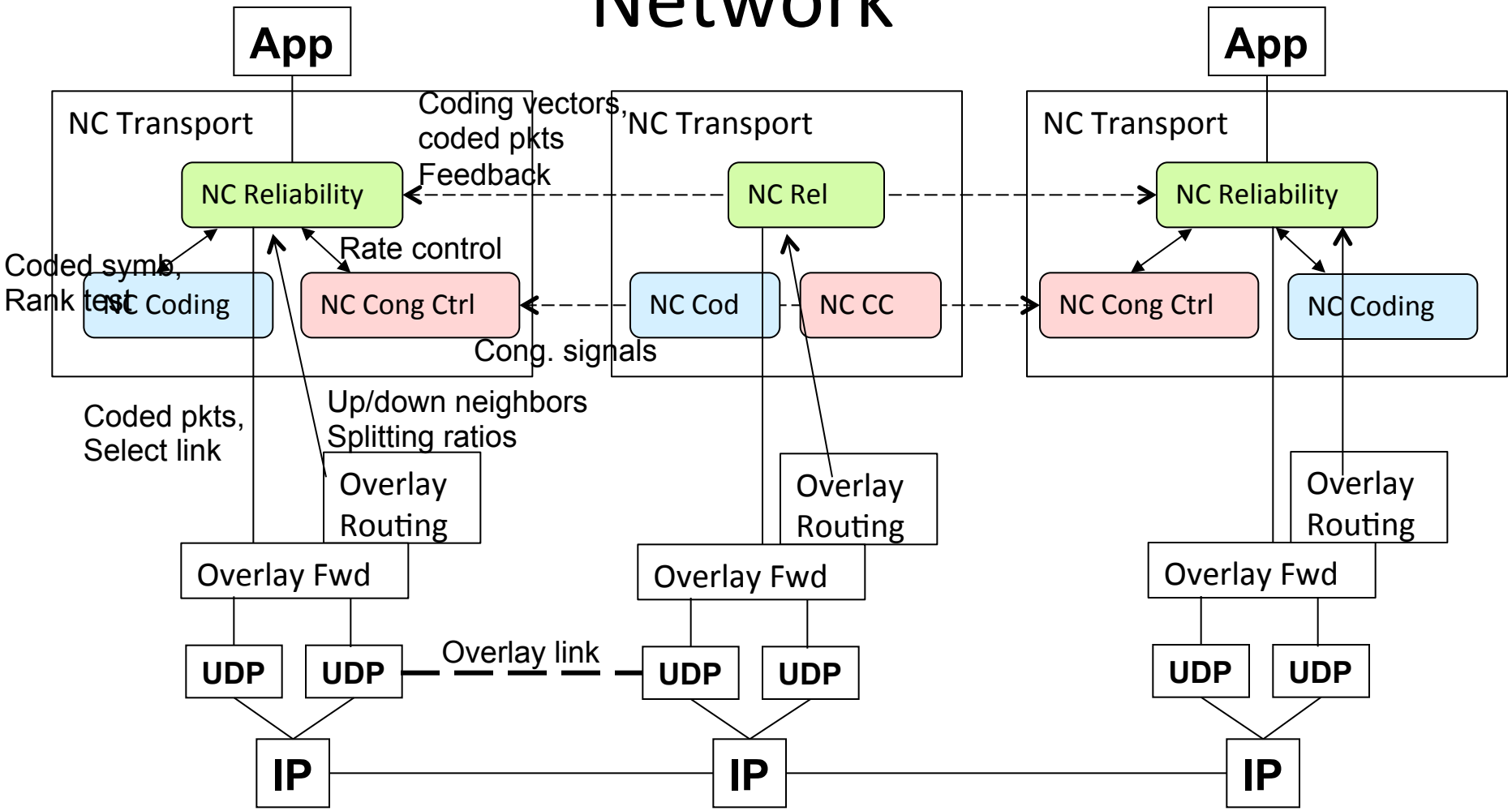
- Ahlswerde et al, 2000
  - Network coded multicast achieves max flow-min cut
- S Li et al 2003
  - Linear coding w/ finite symbol size- sufficient for multicast
- Koetter, Medard 2003
  - Algebraic framework for linear network-coding
  - Min-cut max-flow achieved w time-invariant solutions for networks 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



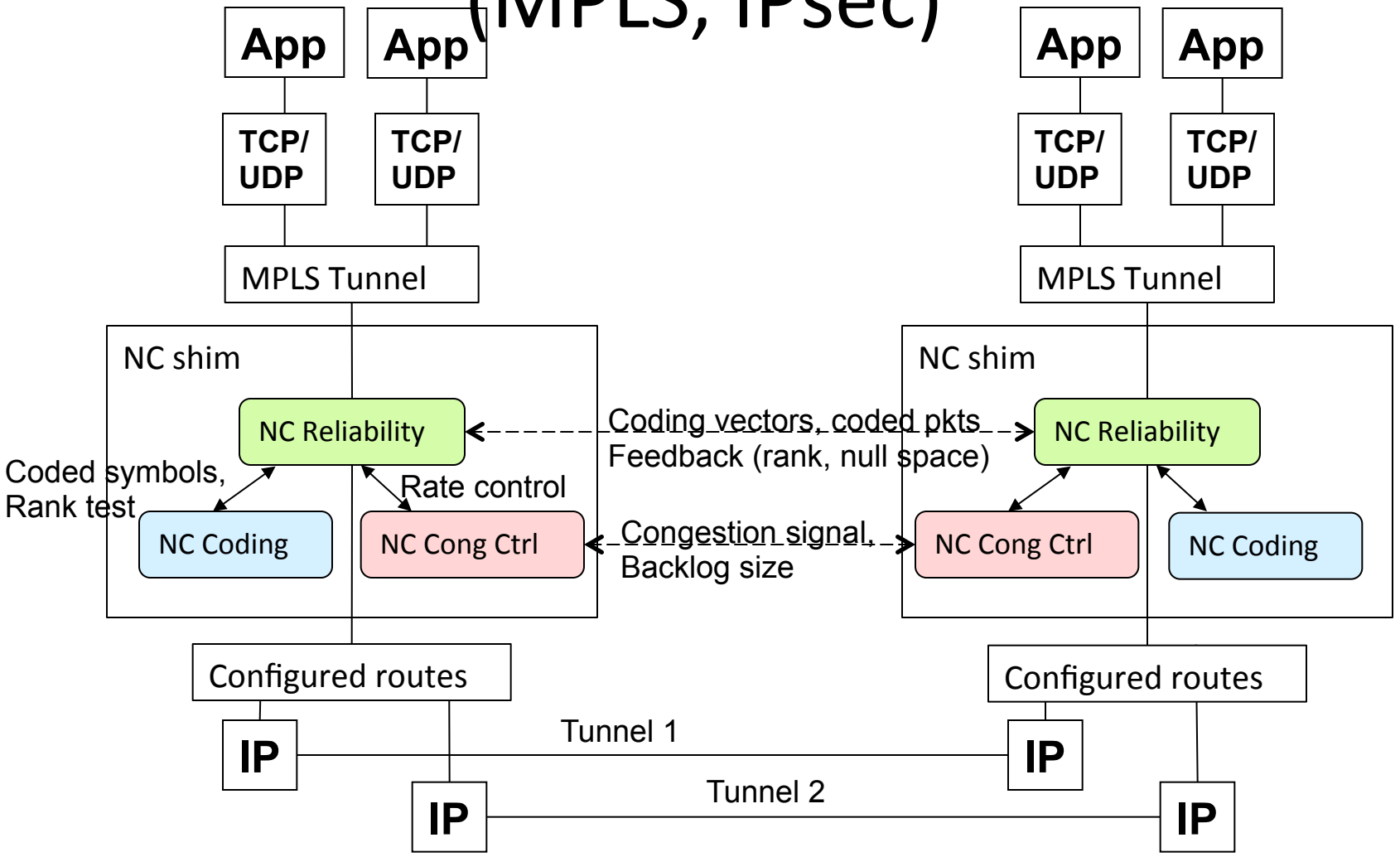
- Coding: end-end. Passes CC signaling.
- Optional: in-network re-coding.
- Coding nodes determined by: static configuration, routing or control signaling.
- Usage: reliability, similar to source coding.

Use Case 3: NC Transport over Overlay Network



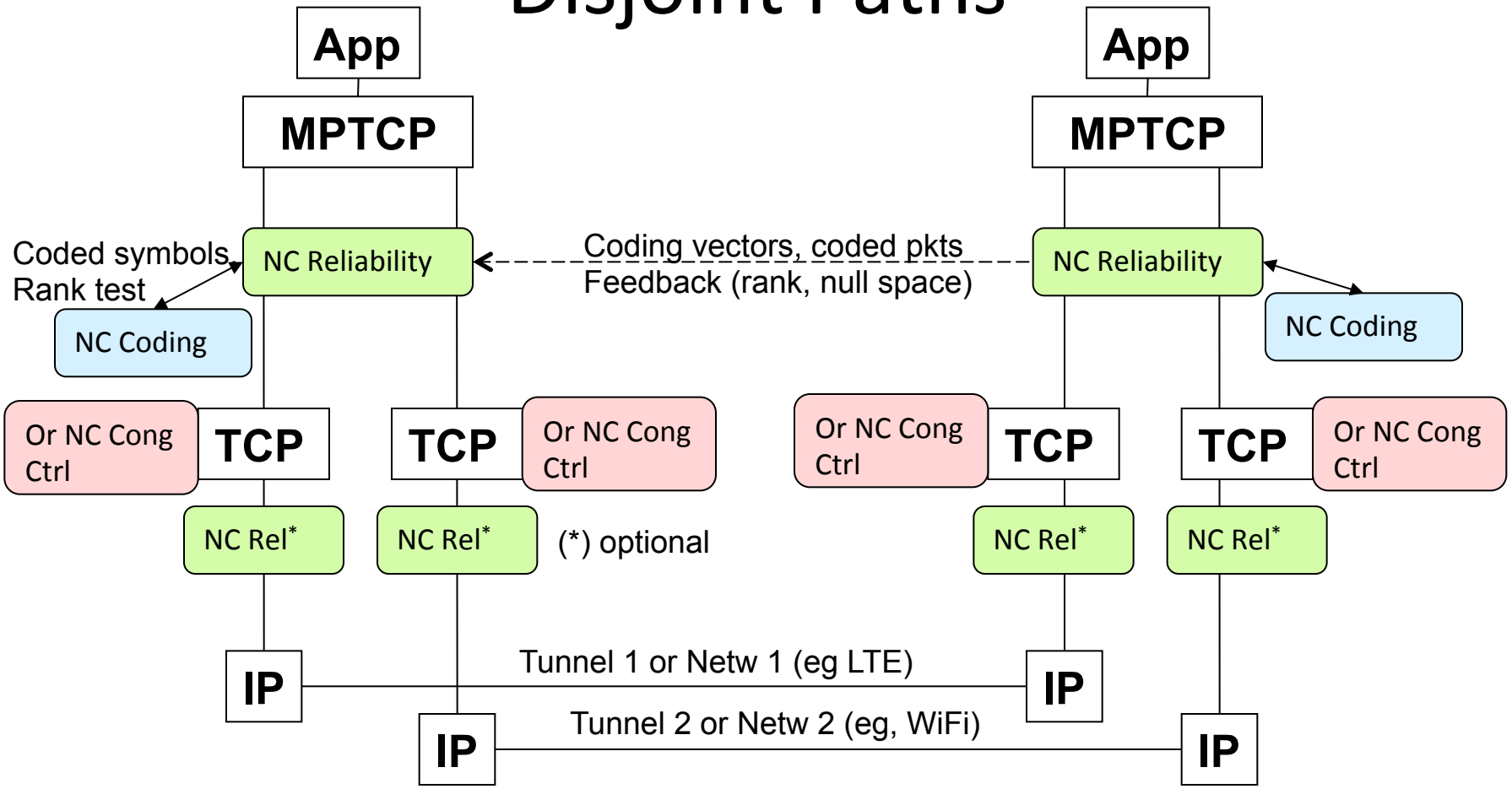
- Overlay links can be reliable (TCP) or unreliable (UDP).
- Requires both reliability and congestion control functions
- Usage: reliability, resilience to link and node outage, anonymity.

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