Network Coding and Multihop Wireless Networks

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Motivation/Goal

• Use-case in wireless multihop networks
  – **Firmware updates for “Low power and Lossy Networks” (LLNs)**
  – Timely: SUIT (Software Updates for Internet of Thing) BOF was Monday afternoon
  – Requires multihop broadcast of many packets

• General feature, broadcast/multicast:
  – Broadcast/multicast in MANET (ad-hoc) networks
    • OLSR (RFC3626), OSPF-MPR (RFC5449), SMF (RFC6621)
  – Broadcast/multicast in ROLL (LLNs)
    • MPL – Multicast Protocol for LLN (ROLL), RFC 7731 (2016)
    • Drafts in ROLL wg: CCAST (2017), RPL-BIER (2017),…
Wireless Multicast Advantage

• One transmitter - many receivers
• Multihop/Broadcast
  – Ex: Subset of repeaters

• Design constraint: Wireless Ack. Disadvantage
• Efficient control plane not straightforward
Wireless Multihop Broadcast NC: DRAGONCAST

- **DRAGONCAST (2008) – Broadcast for MANET/ad-hoc**
  - https://www.ietf.org/archive/id/draft-adjih-dragoncast-00.txt

- **DragonNet (2014) – Broadcast for LLNs/IoT**

- **Principle 1 - Every node send coded payloads,**
  - “Control plane”: State is piggybacked (alleviate ack problem)

- **Principle 2 - Local control: each node helps neighbors,**
  - D.R.A.G.O.N. (龍): adjust transmission rate
  - SEW (Sliding Encoding Window):
    - Maintains decoding buffer with coded payloads
    - Generates packets useful for neighbors
**Principle 1: Control Plane (Neighbor Information Set)**

**<Transmitter State>**
- **Buffer:**
  - $P_3 + P_4$
  - $P_3 + P_5$
  - $P_3 + 4P_6$
- **State:**
  - Decoded up to $P_2$
  - Rank = 3
  - Window 3 to 6 ($P_3$ to $P_6$)

**<Packet with coded payload>**
- **Decoded up to $P_2$, rank=3**
  - Window indices: 3 to 6
- **Encoding vector:** $(0, 0, 3, 1, 1, 4, 0, ...)$
- **Content:** $[3P_3 + P_4 + P_5 + 4P_6]$

**<Receiver State>**
- **Buffer:**
  - [...] add: $3P_3 + P_4 + P_5 + 4P_6$
- **State:** [...]  
- **Neighbor Information Set:**
  - Node k: decoded up to $P_2$
  - Rank = 3, window indices: 3 to 6
Principle 2: Local Control
Sliding Encoding Window

- Sliding Encoding Window (SEW module):
  - Consider “first undecoded” of each neighbor
  - Ex: A decoded up to $P_{11}$, B up to $P_9$, C up to $P_{12}$
  - Generated coded payload with $P_{10}, \ldots, P_{10+\text{window}-1}$
Sliding Encoding Window (SEW)

- Decoding buffer LIBLC
  - $P_4 + P_5$
  - $2P_4 + P_6$
  - $3P_4 + 4P_7$

LIBLC (linear coding)
- Fixed sizes (embedded systems)
- Gaussian Elimination (“reversed” RREF)
- preliminary version at: [https://gitlab.inria.fr/GardiNet/liblc](https://gitlab.inria.fr/GardiNet/liblc)

Received packet

decoded packet notification (to app)
Sliding Encoding Window (SEW)

- **Decoding buffer LIBLC**
  - $P_4 + P_5$
  - $2P_4 + P_6$
  - $3P_4 + 4P_7$

- Received packet
- Control info.
- Neighbor State Information
- **SEW**
  - Buffer Mgr
  - Packet Generation
  - Generated coded packet
  - Decoded packet notification
  - (optional) get back already removed packets

- is-full
- remove
- coded packets w/ constraints [index min, index max]
Sliding Encoding Window (SEW)

- Received packet
- Decoding buffer LIBLC
  - $P_4 + P_5$
  - $2P_4 + P_6$
  - $3P_4 + 4P_7$

Neighbor State Information
- Neighbor State Information
- Buffer Mgr
  - is-full
  - remove
- Packet Generation
  - coded packets w/ constraints [index min, index max]

Generated coded packet
- (optional) get back already removed packets
- decoded packet notification
- draft-roca-nwcrg-generic-fec-api ?
CISEW

- **Coding Interval-based Sliding Encoding Window:**

- **Redesign of SEW allowing “desynchronization” (real-time)**
  - Assume limited decoding buffer:
  - Choice between throwing decoded or undecoded packets
  - Combinations may become useless: \( P_{11} + \ldots \) if \( P_{11} \) dropped

- Need for a more general buffer management,
- Need for a more general encoding strategy, and:
- Need for more information about the state of neighbors
  - Updated signaling: unwanted, uninteresting, interesting, unseen

- Discussion (& heuristics) in the draft, several tradeoffs
Thank you

Questions?
Sliding “Encoding” Window (SEW)

- Reversed RREF:
  - $Q_1 = P_4 + P_5$
  - $Q_2 = P_4 + P_6$
  - $Q_3 = P_4 + 4P_7$

- RREF:
  - $Q'_1 = P_4 + P_5$
  - $Q'_2 = P_5 - 4P_7$
  - $Q'_3 = -P_6 + 4P_7$