Network Coding and Multihop Wireless Networks

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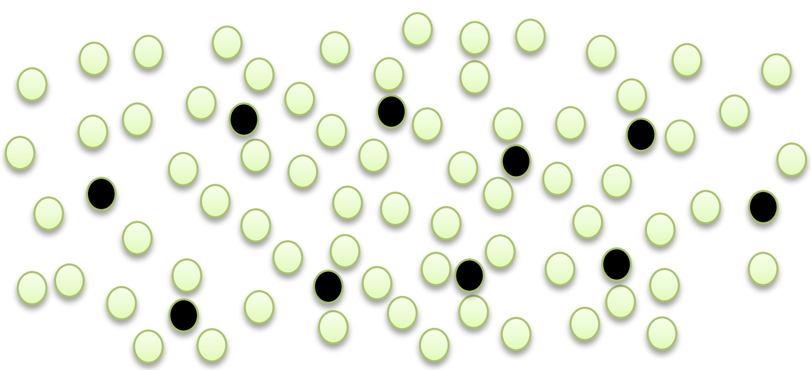
Motivation/Goal

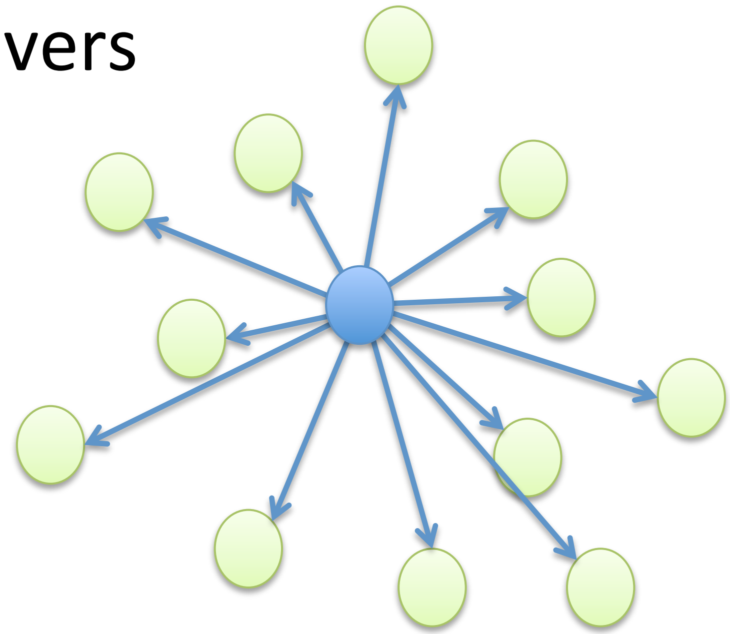
- Use-case in wireless multihop networks
  - **<u>Firmware updates for "Low power and Lossy Networks" (LLNs)</u>**
  - Timely: SUIT (Software Updates for Internet of Thing) BOF was Monday afternoon
  - Requires multihop broadcast of many packets

- 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
  – S-Y. Cho and C. Adjih, "Wireless Broadcast with Network Coding: DRAGONCAST", Inria RR-6569, July 2008; and S-Y. Cho' PhD Thesis (2008)
  – https://www.ietf.org/archive/id/draft-adjih-dragoncast-00.txt
- DragonNet (2014) – Broadcast for LLNs/IoT
  – I. Amdouni, A.Masucci, H. Baccouch, C. Adjih "DragonNet: Specification, Implementation, Experimentation and Performance Evaluation", report, 2014, https://hal.inria.fr/hal-01632790v1
- 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 → **Receiver**

<Transmitter State>

Buffer:

- **P_3+P_4**
- **P_3+P_5**
- **$P_3+4\ P_6$**

State:

Decoded = up to **P_2**,

Rank=3,

Window 3 to 6 (**P_3** to **P_6**)

<Receiver State>

Buffer:

- **[…] add: 3 $P_3+P_4+P_5+4\ P_6$**

State: […]

Neighbor Information Set:

Node k: decoded up to P_2
rank = 3, window indices: 3 to 6

<Packet with coded payload>

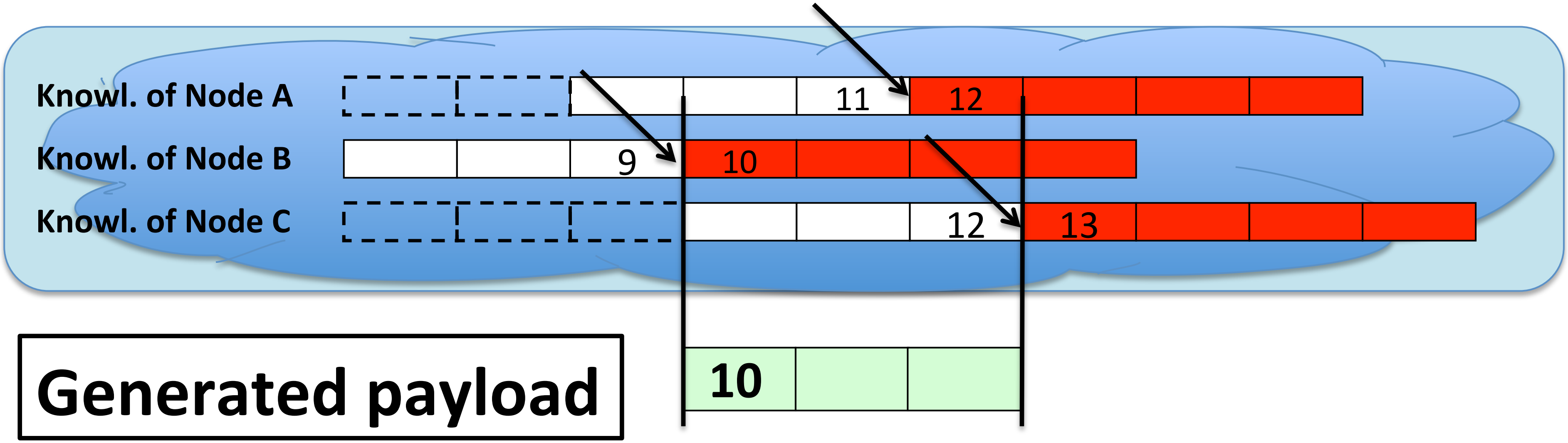
Decoded up to P_2, rank=3
window indices: 3 to 6

Encoding vector=(0,0,3,1,1,4,0,...)

Content = [**3 $P_3+P_4+P_5+4\ P_6$**]

Principle 2: Local Control
Sliding Encoding Window

- Sliding Encoding Window (SEW module):
  - Consider "first undecoded" of each neighbor
  - Ex: A decoded up to $\mathbf{P_{11}}$, B up to $\mathbf{P_{9}}$, C up to $\mathbf{P_{12}}$
    Generated coded payload with $\mathbf{P_{10}}, \ldots, \mathbf{P_{10+window-1}}$



Sliding Encoding Window (SEW)

Received packet

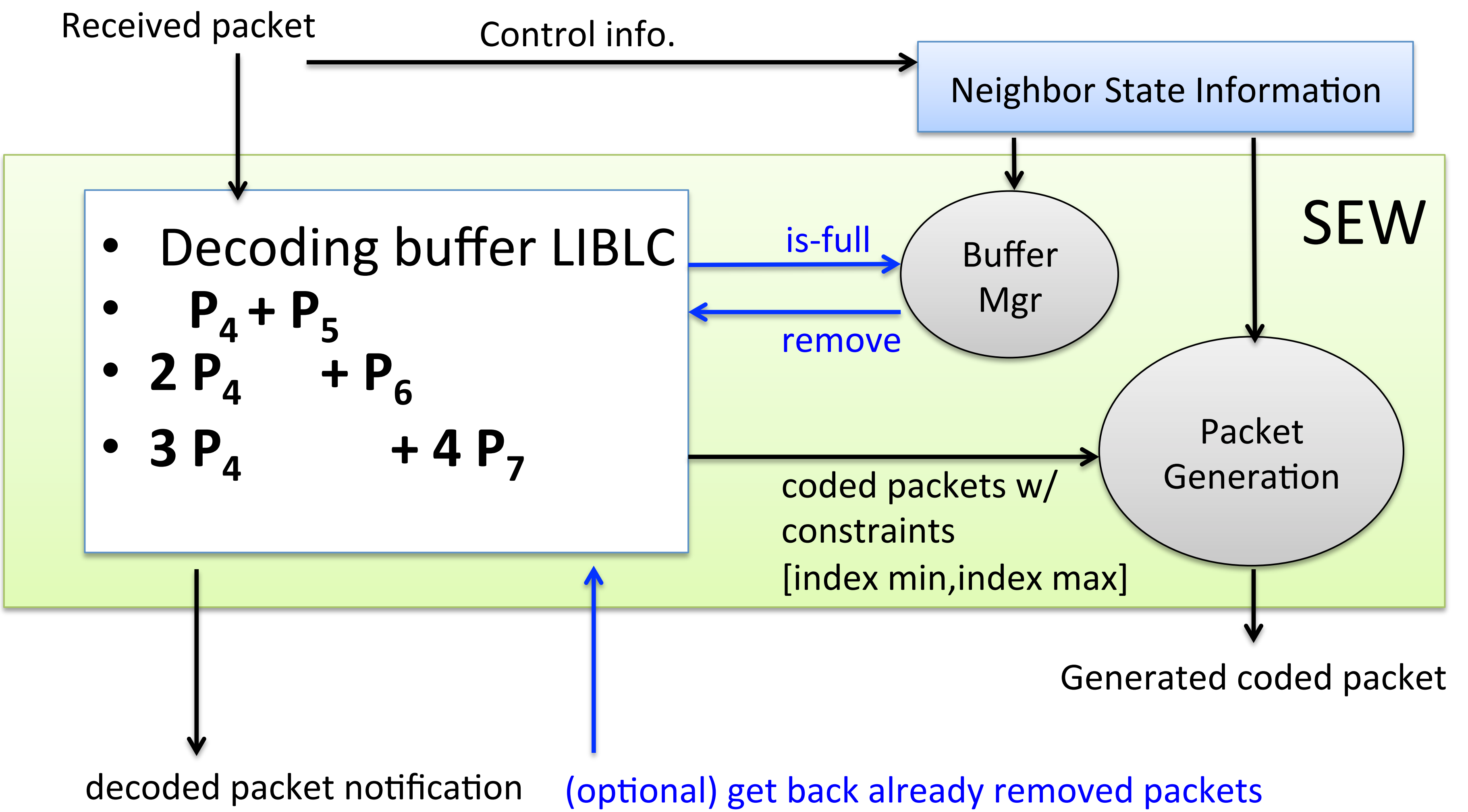
- Decoding buffer LIBLC
- **$P_4 + P_5$**
- **$2\,P_4 + P_6$**
- **$3\,P_4 + 4\,P_7$**

decoded packet notification
(to app)

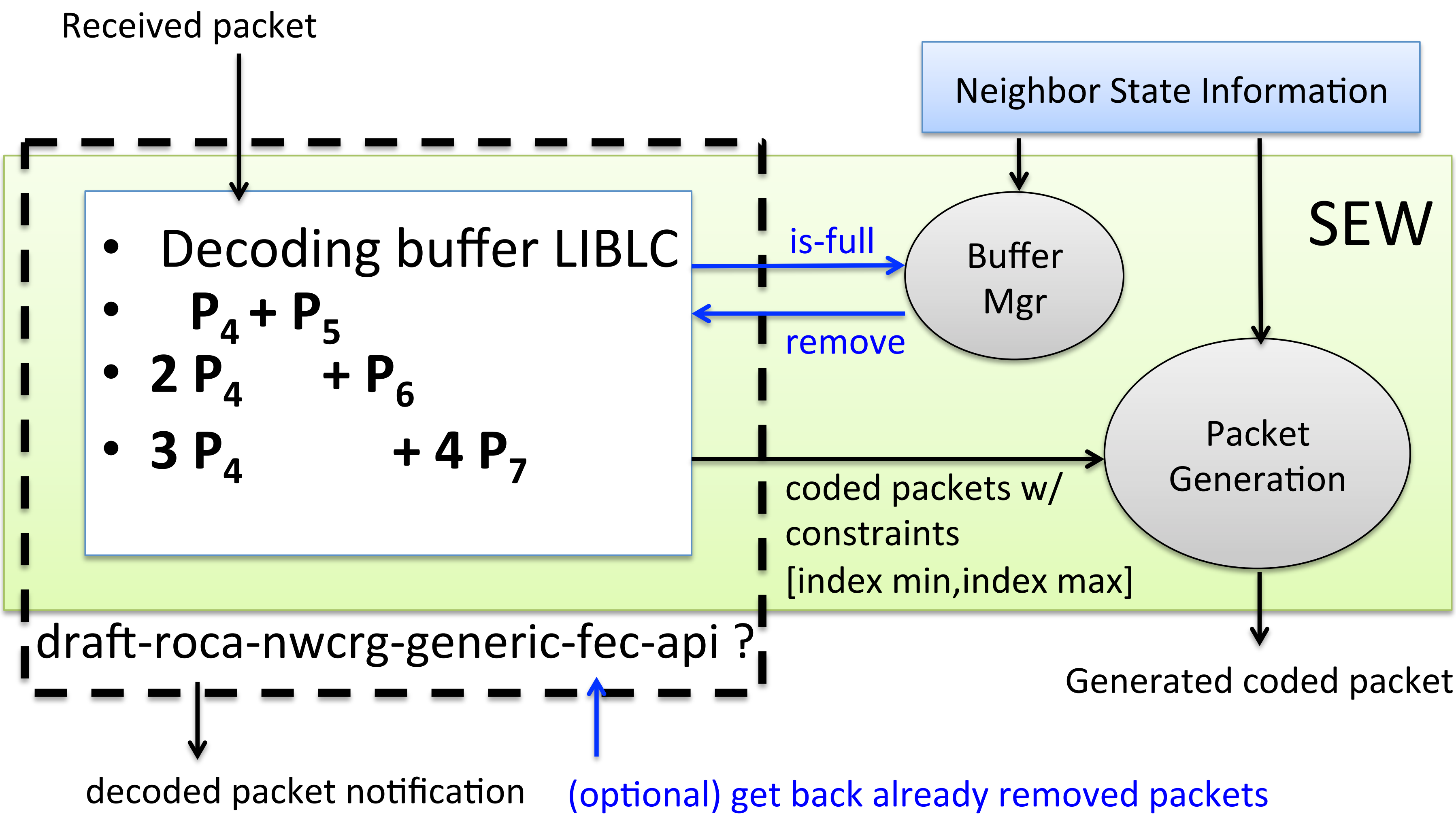
LIBLC (linear coding)

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

Sliding Encoding Window (SEW)

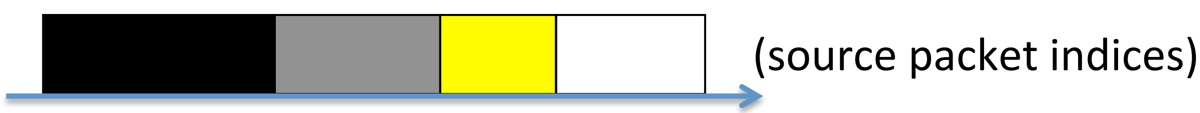


Sliding Encoding Window (SEW)



CISEW

- Coding Interval-based Sliding Encoding Window:
  I.Amdouni, C. Adjih, "Coding Interval-based Sliding Encoding Window", draft-amdouni-nwcrg-cisew-00 (work in progress), July 2014, http: // tools.ietf.org/html/draft-amdouni-nwcrg-cisew-00
- Redesign of SEW allowing "desynchronization" (real-time)
  - Assume limited decoding buffer:
  - Choice between throwing decoded or undecoded packets
  - Combinations may become useless: P_{11}+... 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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Node ID            |        Sequence Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               DRAGON Parameters                               |
|                                               +-+-+-+-+-+-+-+-+
|                                               |               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+               |
|
|               Flow Parameters
|
|                               +-+-+-+-+-
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Coded Data
|
|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
```

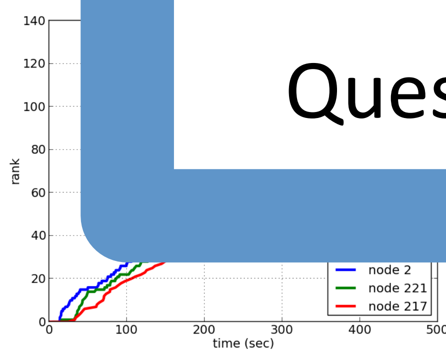
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Rank of the Transmitter    |          High Index           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Low  Index           |      Number of Neighbors      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

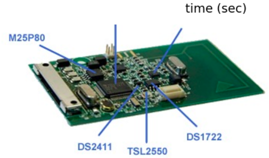
```
        2                   3
4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Sliding Encoding Window Size |
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |
-+-+
```

```
        2                   3
4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |          Coef Pos Max          |
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                                |
|                                                               |
|                      Coded Payload Data                       |
|                               ...                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Thank you

Questions ?





Sliding "Encoding" Window (SEW)

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

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