# Random Linear Network Coding (RLNC)-Based Symbol Representation

# draft-heide-nwcrg-rlnc-00

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# Agenda

1. General motivation and objectives
2. Design goals and features supported
3. Symbol representation types and examples
4. Relationship with an outer protocol and limitations.

General-purpose, **low overhead** representation of "coded" symbols.

# Motivation

1. Representation of coded symbols is a small but essential part of any protocol using network coding.
2. Reuse of representation for faster protocol development.
3. Interoperability between implementations of the underlying code
4. Accommodation of varying frame size and changing link conditions.

All Network Coding Protocols

Protocol 1

Protocol 2

Protocol 3

Symbol representation
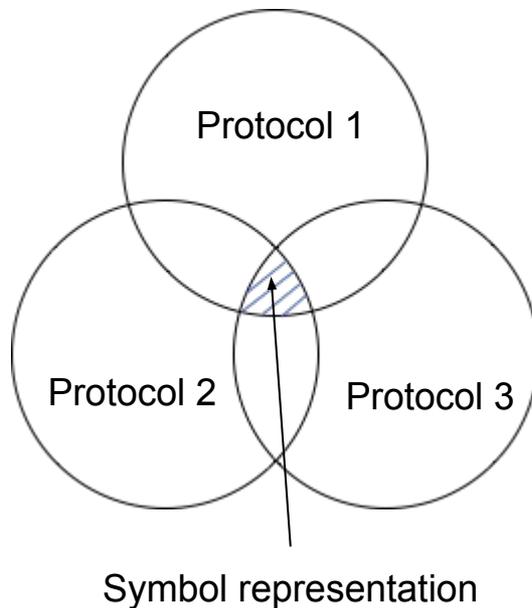
# Design goals and features

Goals

1. Low header overhead
2. Support recoding
3. Generate symbols from incomplete block
4. Support both block and sliding window type code

Resulting supported features

1. Variable number of symbols represented - efficiently
2. 3 symbol types
   a. Uncoded
   b. Coded
   c. Recoded
3. Small and large encoding window
   a. Additional variants could be defined.
4. Parameters that can be defined per stream, packet, representation... defined by outer protocol

# General symbol representation

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  TYPE |    SYMBOLS    |            ENCODER RANK              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                 SEED or CODING COEFFICIENTS                  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                      SYMBOL(S) DATA                          |
|                          ...                                 |
|                                                             |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Figure 4: A general symbol representation design.

# Symbol representation types

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   1   |    SYMBOLS     |           ENCODER RANK              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                     SYMBOL(S) DATA                          |
|                          ...                               |
|                                                            |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Figure 5: A **uncoded** symbol representation.

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   2   |    SYMBOLS     |           ENCODER RANK              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
+         SEED           |          SYMBOL(S) DATA            |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                  SYMBOL(S) DATA continued                  |
|                          ...                               |
|                                                            |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Figure 6: A **coded** symbol representation.

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   3   |    SYMBOLS     |           ENCODER RANK              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                   CODING COEFFICIENTS                      |
|                          ...                               |
|                                                            |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                     SYMBOL(S) DATA                         |
|                          ...                               |
|                                                            |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Figure 7: A **recoded** symbol representation.

# Relation to outer protocol and limitations

Supported by the representation

1.  Any number of representations can be included in a single payload
2.  Up to 15 symbols per representation
3.  Block size / window size up to
    a.  1023 for small representation
    b.  262,143 for large representation

Must be defined by outer protocol / application

1.  Field
2.  Symbol size
3.  Representation type
    a.  Currently small or large
4.  Block id or window offset.

Can be defined (if needed)

5.  Block size
6.  Density (for sparse symbols)
7.  Pseudo random generator
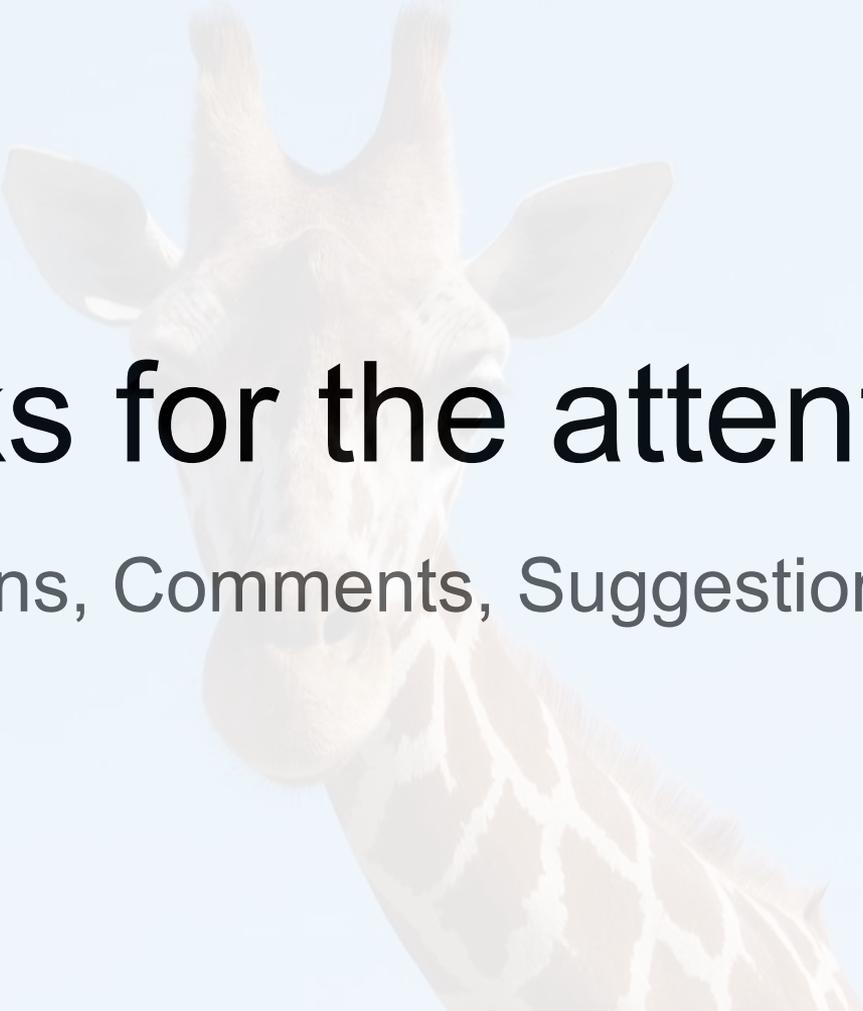
# Thanks for the attention

Questions, Comments, Suggestions?

# Uncoded example

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   1   |       3       |               0                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                    Systematic Symbol 0 Data                  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                    Systematic Symbol 1 Data                  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                    Systematic Symbol 2 Data                  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

Figure 8: A symbol representation with 3 uncoded symbols.
```

# Coded example

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   2   |       2       |               8                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|               4               |      Coded Symbol A Data      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Coded Symbol A Data      |      Coded Symbol B Data      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Coded Symbol B Data      |
+---+---+---+---+---+---+---+---+---+
```
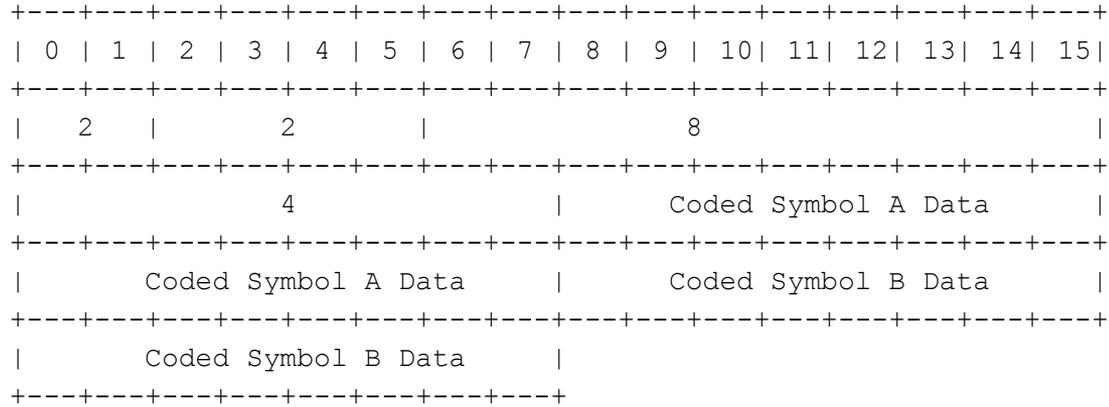
Figure 9: A symbol representation with 2 coded symbols.

# Recoded example

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10| 11| 12| 13| 14| 15|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   2   |       2       |               8                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|             A0                |             A1                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                              ...                              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|             A6                |             A7                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|             B0                |             B1                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                              ...                              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|             B6                |             B7                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                     Coded Symbol A Data                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                     Coded Symbol B Data                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```
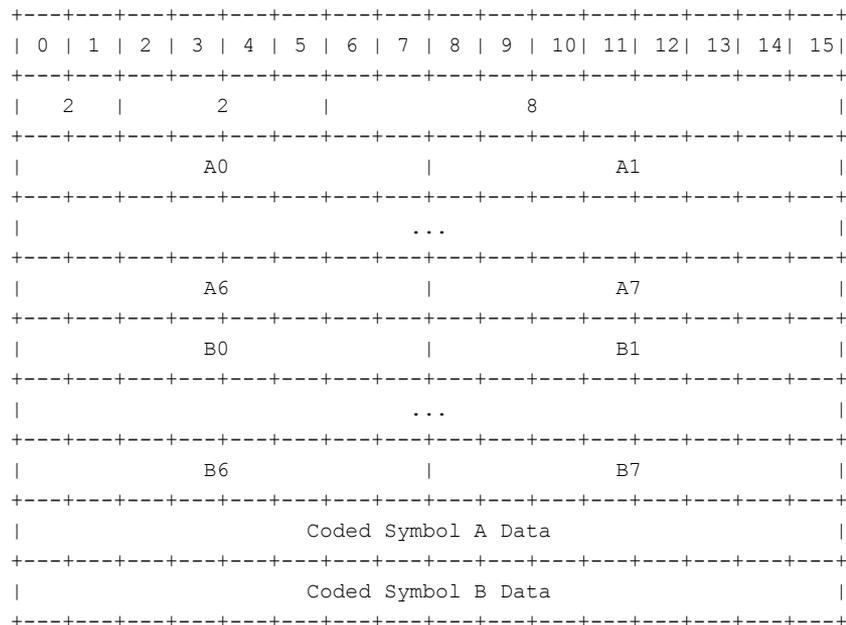
Figure 10: A symbol representation with 2 recoded symbols having
coding coefficients attached.