IPv6 over MS/TP Networks

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Changes since -02

- § 2: Support for 115,200 baud is REQUIRED
- § 4: Support for MSDU length of 1500 octets is RECOMMENDED
- § 8: Format of S/TLLAO is aligned with RFC 4944
- Added Appendix D, Example 6LoBAC Packet Decode
- TBD: Finalize § 12, Security Considerations

Motivation

Develop a low-cost **wired** IPv6 solution for commercial building control applications

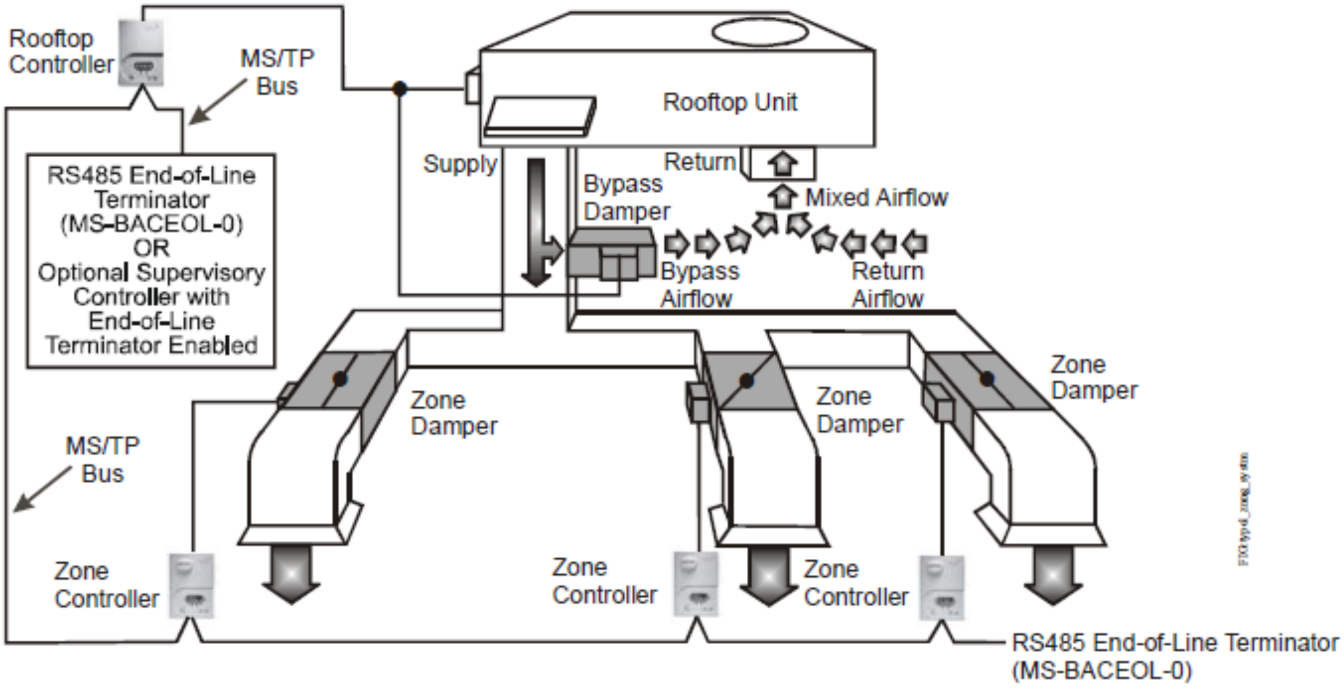


Figure 1: Typical Zoning Control System Installed on a Single MS/TP Bus

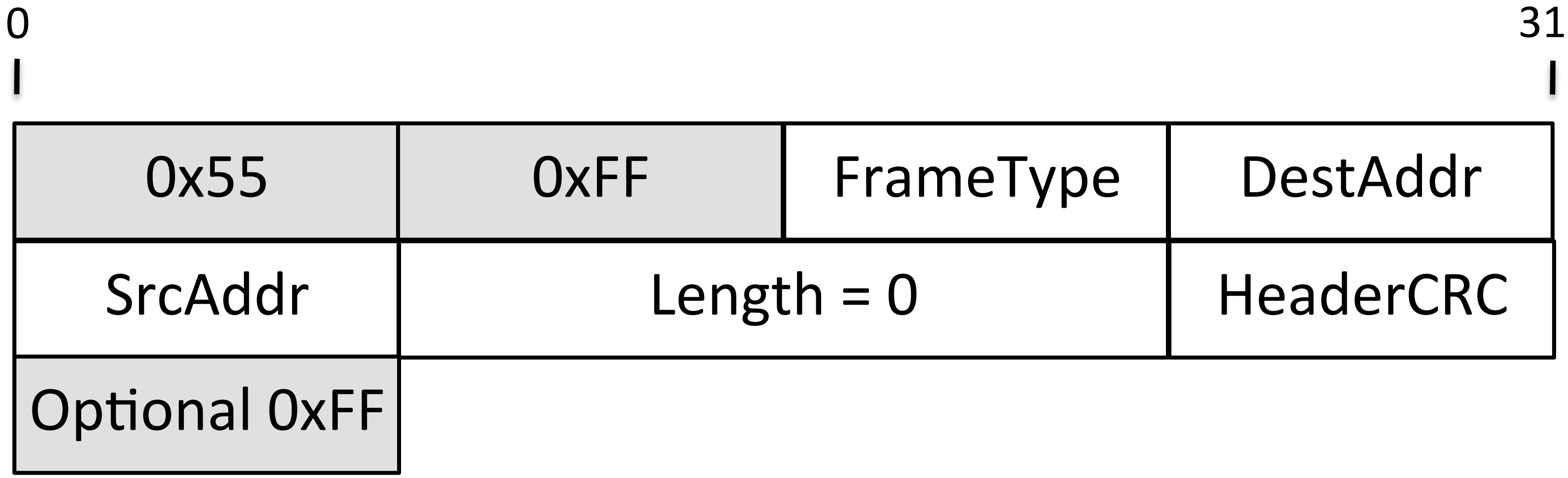
Background

- **BACnet** is the ISO/ANSI/ASHRAE [Standard 135-2012] data communication protocol for Building Automation and Control networks
- **MS/TP** (Master-Slave/Token-Passing) is a widely used data link defined in BACnet
  – Based on RS-485 single twisted pair PHY; supports data rates up to 115.2 kpbs and 1 km diameter
  – Contention-less MAC (token passing bus)
  – Consider it a wired alternative to IEEE 802.15.4

Technical Approach

- Leverage elements of 6LoWPAN [RFC 4944]
- Minimize changes to existing MS/TP specification [BACnet Clause 9]
- Goal: co-existence with legacy MS/TP nodes
  - No changes to frame header format, control frames, or MS/TP Master Node state machine
- MS/TP Extended Frames proposal includes:
  - New frame type for IPv6 (LoBAC) Encapsulation
  - Larger MSDU (1500+ octets)
  - 32-bit FCS (CRC-32K)
  - COBS (Consistent Overhead Byte Stuffing) encoding

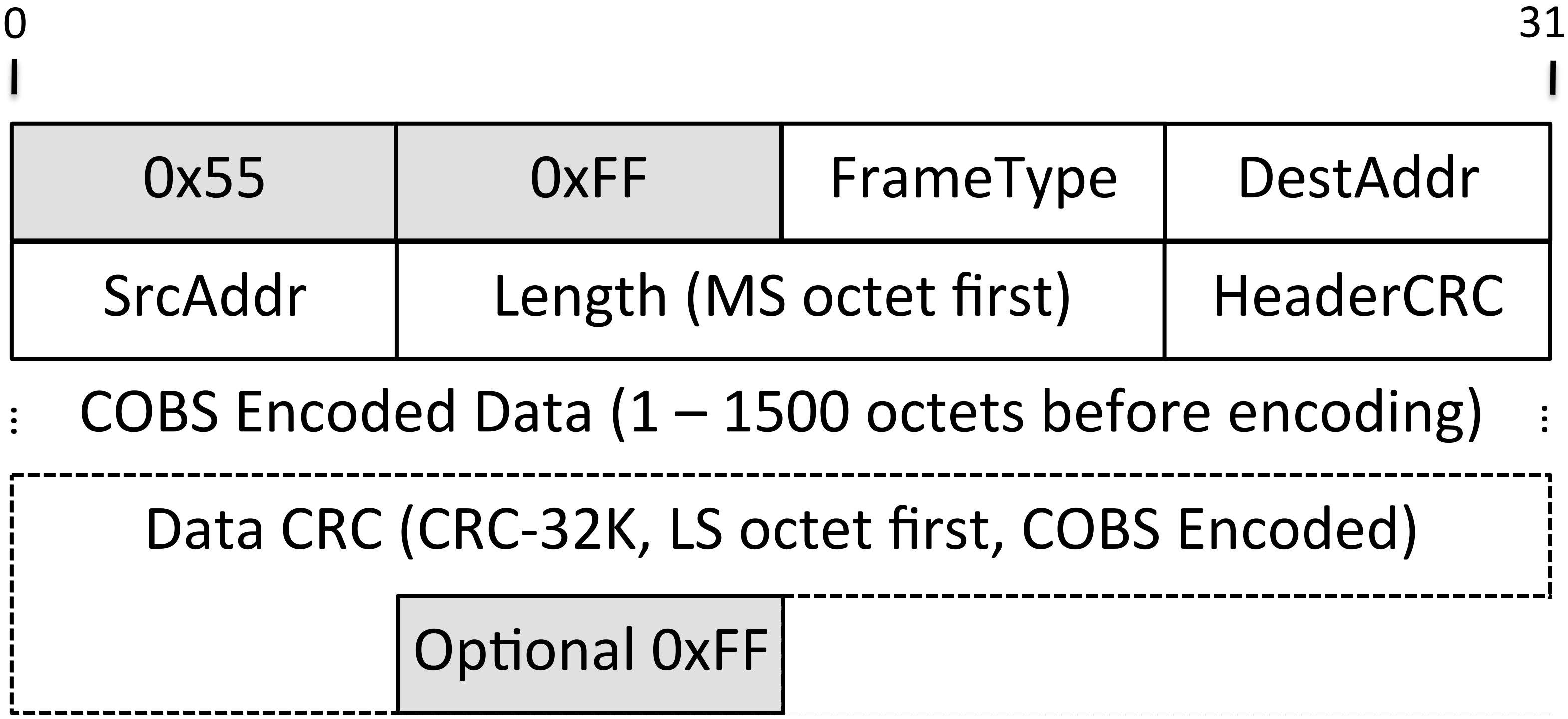
MS/TP Control Frame Format



0x55	0xFF	FrameType	DestAddr
SrcAddr	Length = 0		HeaderCRC
Optional 0xFF			

Frame Type:	0 = Token
	1 = Poll for Master
	2 = Reply to Poll for Master
Destination Address:	0 – 127
Source Address:	0 – 127

MS/TP Encoded Data Frame Format



0

31

0x55

0xFF

FrameType

DestAddr

SrcAddr

Length (MS octet first)

HeaderCRC

COBS Encoded Data (1 – 1500 octets before encoding)

Data CRC (CRC-32K, LS octet first, COBS Encoded)

Optional 0xFF

Frame Type:	34 = IPv6 (LoBAC) Encapsulation
Destination Address:	0 – 127 or 255 (all nodes)
Source Address:	0 – 127

LoBAC Encapsulation

- Uses 6LoWPAN Dispatch Header [RFC 4944]:

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0 1| Dispatch  |  Type-specific header
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Pattern	Header Type
01 1XXXXX	LOWPAN_IPHC – Compressed IPv6 header

LoBAC Encapsulation (cont.)

- No mesh, broadcast, or fragmentation headers
  - One option remains:

IPHC Dispatch	IPHC Header	Payload

A LoBAC encapsulated LOWPAN_IPHC
[RFC 6282] compressed datagram

IPHC Compression [RFC 6282]

- Assumes some 6LBR-like behavior, e.g. 6LoWPAN Context Option (6CO, [RFC 6775])
- Uses 6LoWPAN short address format, formed by appending 8-bit MS/TP address to the octet 0x00
  - For example, an MS/TP node with a MAC address of 0x4F results in the following IPHC short address:

```
|0              1|
|0              5|
+----------------+
|0000000001001111|
+----------------+
```

Stateless Address Auto-Configuration

- Typically, 8-bit MAC address is appended to the seven octets 0x00, 0x00, 0x00, 0xFF, 0xFE, 0x00
  - For example, an MS/TP node with a MAC address of 0x4F results in the following Interface ID:

```
|0              1|1              3|3              4|4              6|
|0              5|6              1|2              7|8              3|
+----------------+----------------+----------------+----------------+
|0000000000000000|0000000011111111|1111111000000000|0000000001001111|
+----------------+----------------+----------------+----------------+
```

- A privacy address **may** be used for the Interface Identifier (SHOULD be for ULA/Global addresses)
  - In this case there **must** be a way to map the address to an 8-bit MAC address (e.g. ARO in NS [RFC 6775])

IPv6 Link Local Address

- The IPv6 link-local address [RFC 4291] for an MS/TP interface is formed by appending the Interface Identifier (defined in previous slide) to the prefix FE80::/64:

```
 10 bits            54 bits                  64 bits
+----------+-----------------------+----------------------------+
|1111111010|         (zeros)       |    Interface Identifier    |
+----------+-----------------------+----------------------------+
```

Unicast Address Mapping

- The Source/Target Link-Layer Address option has the following form when the link layer is MS/TP and the addresses are 8-bit MS/TP MAC addresses:

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Type     |   Length=1    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      0x00     | MS/TP Address |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
+            Padding            +
|          (all zeros)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
Option fields:

Type:
  1 = Source Link-layer address
  2 = Target Link-layer address

 Length:
   The value of this field is
   1 for 8-bit MS/TP addresses

 MS/TP Address:
   The 8-bit MAC address in
   canonical bit order
```

Multicast Address Mapping

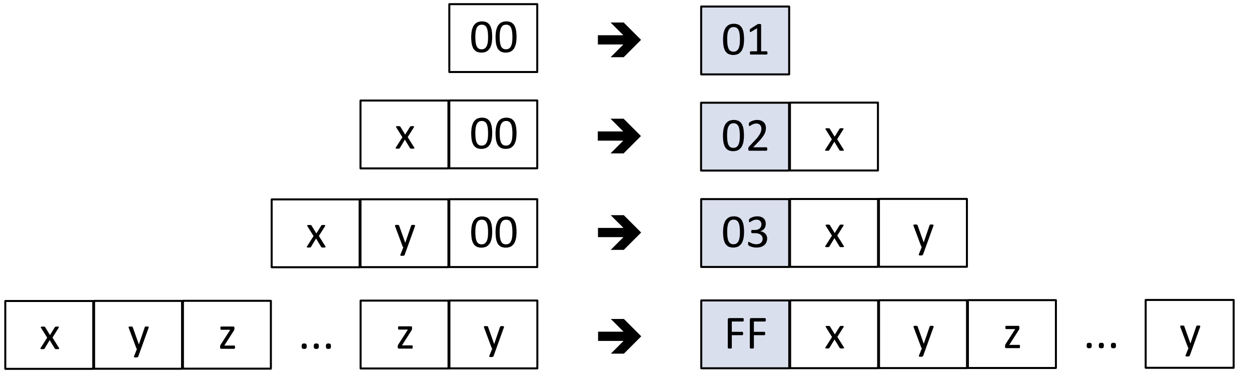
- MS/TP only supports link-local broadcast
- Uses 6LoWPAN short address format, formed by appending 0xFF to the octet 0x00
  - All IPv6 multicasts on the MS/TP link map to the following IPHC short destination address:

```
|0              1|
|0              5|
+----------------+
|0000000011111111|
+----------------+
```

Backup Slides

COBS Encoding Basics

Code	Followed By	Meaning
0x00	(not applicable)	(not allowed)
0x01	nothing	A single zero byte
0x02	one data byte	The single data byte, followed by a zero byte
n	(*n* – 1) data bytes	The (*n* – 1) data bytes, followed by a zero byte
0xFE	253 data bytes	The 253 data bytes, followed by a zero byte
0xFF	254 data bytes	The 254 data bytes, **not** followed by a zero byte



00 ➔ 01

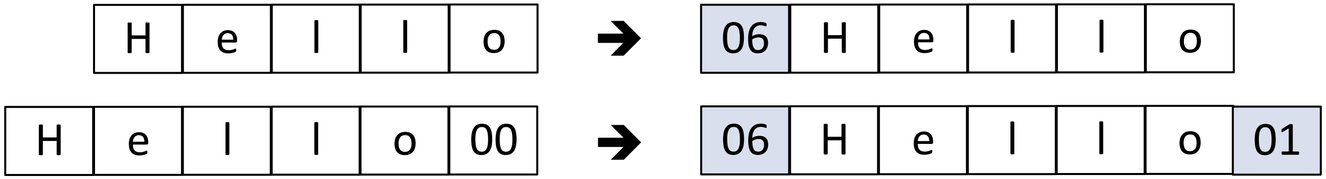
x 00 ➔ 02 x

x y 00 ➔ 03 x y

x y z … z y ➔ FF x y z … y

COBS Encoding in Detail

- "Phantom zero" is appended to input to resolve ambiguity in final code block:



H e l l o ➔ 06 H e l l o

H e l l o 00 ➔ 06 H e l l o 01

- An arbitrary octet (e.g. 0x55) may be removed by XOR-ing it over the COBS encoder **output** stream

- COBS overhead:
  - At least one octet per encoded field
  - At most one octet in 255 (6 octets in 1501; ≈ 0.4%)