IPv6 over MS/TP Networks

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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 135-2010] 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 over 1 km distance without a repeater

• Contentionless MAC (token passing bus)

• 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

<table>
<thead>
<tr>
<th></th>
<th>0x55</th>
<th>0xFF</th>
<th>FrameType</th>
<th>DestAddr</th>
</tr>
</thead>
<tbody>
<tr>
<td>SrcAddr</td>
<td>Length = 0</td>
<td></td>
<td>HeaderCRC</td>
<td></td>
</tr>
<tr>
<td>Optional 0xFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Frame Type:
- 0 = Token
- 1 = Poll for Master
- 2 = Reply to Poll for Master

Destination Address: 0 – 127
Source Address: 0 – 127
MS/TP Extended Data Frame Format

<table>
<thead>
<tr>
<th>Bit</th>
<th>Bit Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0x55</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0xFF</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>FrameType</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>DestAddr</td>
<td></td>
</tr>
<tr>
<td>0-30</td>
<td>SrcAddr</td>
<td>Length (MS octet first)</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>HeaderCRC</td>
</tr>
</tbody>
</table>

- **COBS Encoded Data (1 – 1501 octets)**
- **+ DataCRC (CRC-32K, LS octet first)**

**Optional 0xFF**

**Frame Type:** 10 = IPv6 (LoBAC) Encapsulation

**Destination Address:** 0 – 127, 255 (broadcast)

**Source Address:** 0 – 127
## COBS Encoding Basics

<table>
<thead>
<tr>
<th>Code</th>
<th>Followed By</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>(not applicable)</td>
<td>(not allowed)</td>
</tr>
<tr>
<td>0x01</td>
<td>nothing</td>
<td>A single zero byte</td>
</tr>
<tr>
<td>0x02</td>
<td>one data byte</td>
<td>The single data byte, followed by a zero byte</td>
</tr>
<tr>
<td>$n$</td>
<td>$(n - 1)$ data bytes</td>
<td>The $(n - 1)$ data bytes, followed by a zero byte</td>
</tr>
<tr>
<td>0xFE</td>
<td>253 data bytes</td>
<td>The 253 data bytes, followed by a zero byte</td>
</tr>
<tr>
<td>0xFF</td>
<td>254 data bytes</td>
<td>The 254 data bytes, not followed by a zero byte</td>
</tr>
</tbody>
</table>

### Examples

```
x
y
z
...
```

- **0x00** followed by **0x01**
  - $x$ 00 ➔ 01

- **0x02** followed by **0x03**
  - $x$ 00 ➔ 02 $x$
  - $x$ $y$ 00 ➔ 03 $x$ $y$

- **0xFF** followed by **0xFF**
  - $x$ $y$ $z$ ... $z$ $y$ ➔ FF $x$ $y$ $z$ ... $y$

```
COBS Encoding in Detail

• "Phantom zero" is appended to input to resolve ambiguity in final code block:
  
  \[\text{Hello} \rightarrow \text{06 Hello}\]
  
  \[\text{Hello00} \rightarrow \text{06 Hello01}\]

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

• COBS overhead:
  - At least, one octet
  - At most, one octet in 255 (6 octets in 1501; \(\approx 0.4\%\))
LoBAC Encapsulation

- Uses 6LoWPAN Dispatch Header [RFC 4944]:

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

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Header Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 XXXXX</td>
<td>NALP – Not a LoWPAN (LoBAC) frame</td>
</tr>
<tr>
<td>01 000000</td>
<td>ESC – Additional Dispatch octet follows</td>
</tr>
<tr>
<td>01 000001</td>
<td>IPv6 – Uncompressed IPv6 header</td>
</tr>
<tr>
<td>...</td>
<td>Reserved by RFC 4944</td>
</tr>
<tr>
<td>01 1XXXXX</td>
<td>LOWPAN_IPHC – Compressed IPv6 header</td>
</tr>
</tbody>
</table>
LoBAC Encapsulation (cont.)

- No mesh, broadcast, or fragmentation headers
  - Two options remain:

```
<table>
<thead>
<tr>
<th>IPv6 Dispatch</th>
<th>IPv6 Header</th>
<th>Payload</th>
</tr>
</thead>
</table>

A LoBAC encapsulated IPv6 datagram
```

```
<table>
<thead>
<tr>
<th>IPHC Dispatch</th>
<th>IPHC Header</th>
<th>Payload</th>
</tr>
</thead>
</table>

A LoBAC encapsulated LOWPAN_IPHC [RFC 6282] compressed datagram
IPHC Compression [RFC 6282]

- Assumes some 6LBR-like behavior, e.g. context distribution
- 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 |
+----------------+
|000000001001111|
+----------------+
```
Stateless Address Autoconfiguration

• 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:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>1</th>
<th>3</th>
<th>3</th>
<th>4</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

+----------------+----------------+----------------+----------------+
| 0000000000000000 | 0000000011111111 | 1111111000000000 | 0000000001001111 |
+----------------+----------------+----------------+----------------+

• An EUI-64 **may** be used for the Interface Identifier
  – In this case there **must** be a way to map the IID to an 8-bit MAC address (e.g. registration or DAD)
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:

```
+----------+-----------------------+----------------------------+
| 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   |     1 = Source Link-layer address
|+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
|     0x00      | MS/TP Address |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
|                               | The value of this field is
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
|         (all zeros)           | 1 for 8-bit MS/TP addresses
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
```

Option fields:

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

Length:
- 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|
+----------------+
```
Thank You

• What remains to be done for WGLC? Please review draft-ietf-6man-6lobac and comment.
• Questions?