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Transmission of IPv6 over MS/TP Networks
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Abstract

MS/TP (Master-Slave/Token-Passing) is a contention-free access method for the TIA-485-A physical layer that is used extensively in building automation networks. This document describes the frame format for transmission of IPv6 packets and the method of forming link-local and statelessly autoconfigured IPv6 addresses on MS/TP networks.

Status of this Memo

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1. Introduction

MS/TP (Master-Slave/Token-Passing) is a contention-free access method for the [TIA-485-A] physical layer that is used extensively in building automation networks. This document describes the frame format for transmission of IPv6 [RFC2460] packets and the method of forming link-local and statelessly autoconfigured IPv6 addresses on MS/TP networks. The general approach is to adapt elements of the 6LoWPAN [RFC4944] specification to constrained wired networks.

An MS/TP device is typically based on a low-cost microcontroller with limited processing power and/or memory. Together with low data rates and a small address space, these constraints are similar to those faced in 6LoWPAN networks and suggest some elements of that solution might be applied. MS/TP differs significantly from 6LoWPAN in at least three respects: a) MS/TP devices typically have a continuous source of power, b) all MS/TP devices on a segment can communicate directly so there are no hidden node or mesh routing issues, and c) proposed changes to MS/TP will support payloads of up to 1500 octets without the need for MAC-layer fragmentation and reassembly.

The following sections provide a brief overview of MS/TP, then describe how to form IPv6 addresses and encapsulate IPv6 packets in MS/TP frames. This document also defines mechanisms for header compression required to make IPv6 practical on MS/TP networks based on [I-D.ietf-6lowpan-hc].

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Abbreviations Used

ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers (http://www.ashrae.org)

BACnet: An ISO/ANSI/ASHRAE Standard Data Communication Protocol for Building Automation and Control Networks

MAC: Medium Access Control

MSDU: MAC Service Data Unit (MAC client data)

MTU: Maximum Transmission Unit (data link client data)

UART: Universal Asynchcronous Transmitter/Receiver

1.3. MS/TP Overview

This section provides a brief overview of MS/TP, which is specified in Clause 9 of ANSI/ASHRAE 135-2010 [BACnet] and included herein by reference. [BACnet] also covers physical layer deployment options.

MS/TP is designed to enable multidrop networks over shielded twisted pair wiring. It can support segments up to 1200 meters in length or data rates up to 115,200 baud (at this data rate the segment length is limited to 1000 meters). An MS/TP link requires only a UART, a 5ms resolution timer, and a [TIA-485-A] transceiver with a driver that can be disabled. These features combine to make MS/TP a cost-effective field bus for the most numerous and least expensive devices in a building automation network.

The differential signaling used by [TIA-485-A] requires a contention-free MAC. MS/TP uses a token to control access to a bus network. A master node may initiate the transmission of a data frame when it holds the token. After sending at most a configured maximum number of data frames, a master node pasess the token to the next master node. (Slave nodes transmit only when polled and are not considered part of this specification.)

MS/TP frames have the following format*:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      0x55     |      0xFF     |  Frame Type*  |      DA       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      SA       |    Length (MS octet first)    |   Header CRC  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
/
/ Data*
/
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Data CRC* (LS octet first)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| optional 0xFF |
+-+-+-+-+-+-+-+-+
```

Figure 1: MS/TP Frame Format

*Note: The Data and Data CRC fields are present only if Length is non-zero. A BACnet proposal now under review assigns a new Frame Type for IPv6, sets the maximum length of the Data field to 1500 octets, and replaces the 16-bit Data CRC with a 32-bit Data CRC.

The MS/TP frame fields have the following descriptions:

Preamble	two octet preamble: 0x55, 0xFF
Frame Type	one octet
Destination Address	one octet node identifier
Source Address	one octet node identifier
Length	two octets, most significant octet first
Header CRC	one octet
Data	0 - 1500 octets* (present only if Length is non-zero)
Data CRC	four octets*, least significant octet first (present only if Length is non-zero)
(pad)	(optional) at most one octet of trailer: 0xFF

The Frame Type is used to distinguish between different types of MAC frames. Currently defined types (in decimal) are:

```
00  Token
01  Poll For Master
02  Reply To Poll For Master
    ...
10  IPv6 over MS/TP Encapsulation*
```

Frame Types 11 through 127 are reserved for assignment by ASHRAE. Frame Types 128 through 255 are available to vendors for proprietary frames. Token, Poll For Master, and Reply to Poll For Master frames MUST be understood by all master nodes. See Section 2 for additional details.

The Destination and Source Addresses are each one octet in length. See Section 3 for additional details.

The Length field specifies the length in octets of the Data field and is transmitted most significant octet first. See Section 4 for additional details.

The Header CRC field covers the Frame Type, Destination Address, Source Address, and Length fields.

The Data and Data CRC fields are conditional on the Frame Type and the Length. The Data and Data CRC fields are always present in frames specified by this document. *See previous note regarding the [BACnet] change proposal to support IPv6 over MS/TP.

The Header and Data CRC generation and check procedures are specified in [BACnet] and exended by the proposal.

2. MS/TP Mode for IP

The [BACnet] MS/TP change proposal now under review allocates a new Frame Type from the reserved range to indicate IPv6 encapsulation. The new Frame Type for IPv6 over MS/TP Encapsulation (LoBAC) is 10.

All MS/TP master devices (including those that support IPv6) must understand Token, Poll For Master, and Reply to Poll For Master frames and support the Receive Frame and Master Node state machines specified in [BACnet] and extended by the proposal.

3. Addressing Modes

MS/TP Destination and Source Addresses are one octet in length. A Destination Address of 255 (0xFF) denotes a link-level broadcast (all nodes). All IPv6 multicast packets MUST be sent to Destination Address 255 and filtered at the IPv6 layer. A Source Address of 255 MUST NOT be used.

[BACnet] specifies that addresses 0 to 127 are valid for master nodes. However, this specification restricts the allowable unicast address range to between 1 and 127, inclusive. Zero MUST NOT be used as either a Destination Address or Source Address.

The assignment of node addresses (identifiers) is outside the scope of this document. Each node must have a unique identifier on the link or a misconfiguration condition exists.

This document assumes that each MS/TP link maps to a unique IPv6 subnet prefix. Hosts learn IPv6 prefixes via router advertisements according to [RFC4861]. MS/TP does not support multicast, therefore IPv6-level multicast packets MUST be carried as link-layer broadcast frames in MS/TP networks.

4. Maximum Transmission Unit

The [BACnet] MS/TP change proposal now under review requires that the MSDU be increased to 1500 octets and covered by a 32-bit CRC. This is sufficient to convey an MTU of at least 1280 octets as required by IPv6 and eliminates the need for MAC-layer fragmentation and reassembly.

However, the relatively low data rates of MS/TP still make a compelling case for header compression. Since it is expected that many (if not all) applications of IPv6 over MS/TP will make use of header compression, an adaptation layer to compress and decompress

IPv6 headers is specified below in Section 5 and the compression scheme is specified in Section 9.

5. LoBAC Adaptation Layer

The encapsulation formats defined in this section (subsequently referred to as the "LoBAC encapsulation") comprise the payload (MSDU) of an MS/TP frame. The LoBAC payload (e.g., an IPv6 packet) follows an encapsulation header stack. LoBAC is a subset of the LoWPAN encapsulation defined in [RFC4944]. Use of the "LOWPAN" prefix where it appears below is therefore intentional. The primary differences are a) elimination of the mesh, broadcast, and fragmentation headers, and b) use of LOWPAN_IPHC compression [I-D.ietf-6lowpan-hc].

All LoBAC encapsulated datagrams transported over MS/TP are prefixed by an encapsulation header stack. Each header in the header stack contains a header type followed by zero or more header fields. Whereas in an IPv6 header the stack would contain, in the following order, addressing, hop-by-hop options, routing, fragmentation, destination options, and finally payload [RFC2460]; in a LoBAC header the analogous header sequence is (optionally) compression and payload. These examples show the header stacks that may be used in a LoBAC network.

A LoBAC encapsulated IPv6 datagram:

```
+---------------+------------+---------+
| IPv6 Dispatch | IPv6 Header | Payload |
+---------------+------------+---------+
```

A LoBAC encapsulated LOWPAN_IPHC compressed IPv6 datagram:

```
+---------------+------------+---------+
| IPHC Dispatch | IPHC Header | Payload |
+---------------+------------+---------+
```

All protocol datagrams (e.g., IPv6, compressed IPv6 headers, etc.) SHALL be preceded by one of the valid LoBAC encapsulation headers, examples of which are given above. This permits uniform software treatment of datagrams without regard to the mode of their transmission.

The definition of LoBAC headers consists of the dispatch value, the definition of the header fields that follow, and their ordering constraints relative to all other headers. Although the header stack structure provides a mechanism to address future demands on the LoBAC (LoWPAN) adaptation layer, it is not intended to provided general purpose extensibility. This format document specifies a small set of header types using the header stack for clarity, compactness, and orthogonality.

5.1. Dispatch Type and Header

The dispatch type is defined by a zero bit as the first bit and a one bit as the second bit. The dispatch type and header are shown here:

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Dispatch: 6-bit selector. Identifies the type of header immediately following the Dispatch Header.

type-specific header: A header determined by the Dispatch Header.

Figure 2: Dispatch Type and Header

The dispatch value may be treated as an unstructured namespace. Only a few symbols are required to represent current LoBAC functionality. Although some additional savings could be achieved by encoding additional functionality into the dispatch octet, these measures would tend to constrain the ability to address future alternatives.

Pattern	Header Type	
00 xxxxxx	NALP	- Not a LoWPAN (LoBAC) frame
01 000000	ESC	- Additional Dispatch octet follows
01 000001	IPv6	- Uncompressed IPv6 Addresses
...	reserved	- Reserved for future use
01 1xxxxx	LOWPAN_IPHC	- LOWPAN_IPHC compressed IPv6

Figure 3: Dispatch Value Bit Pattern

NALP: Specifies that the following bits are not a part of the LoBAC encapsulation, and any LoBAC node that encounters a dispatch value of 00xxxxxx shall discard the packet. Other non-LoBAC protocols that wish to coexist with LoBAC nodes should include an octet matching this pattern immediately following the MS/TP header.

ESC: Specifies that the following header is a single 8-bit field for the Dispatch value. It allows support for Dispatch values larger than 127.

IPv6: Specifies that the following header is an uncompressed IPv6 header [RFC2460].

LOWPAN_IPHC: A value of 001xxxxx specifies a LOWPAN_IPHC compression header (see Section 9.)

6. Stateless Address Autoconfiguration

This section defines how to obtain an IPv6 Interface Identifier. The general procedure is described in Appendix A of [RFC4291], "Creating Modified EUI-64 Format Interface Identifiers".

The Interface Identifier may be based on an [EUI-64] identifier assigned to the device. In this case, the Interface Identifier is formed from the EUI-64 by inverting the "u" (universal/local) bit according to [RFC4291]. This will result in a globally unique Interface Identifier.

If the device does not have an EUI-64, then the Interface Identifier is formed by taking the MS/TP node identifier and concatenating it to the seven octets 0x00, 0x00, 0x00, 0xFF, 0xFE, 0x00, 0x00. For example, an MS/TP node identifier of hexadecimal value 0x4F results in the following Interface Identifier:

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

Note that this results in the universal/local bit set to "0" to indicate local scope.

A different MAC address set manually or by software MAY be used to derive the Interface Identifier. If such a MAC address is used, its global uniqueness property should be reflected in the value of the universal/local bit.

An IPv6 address prefix used for stateless autoconfiguration [RFC4862] of an MS/TP interface MUST have a length of 64 bits.

7. IPv6 Link Local Address

The IPv6 link-local address [RFC4291] for an MS/TP interface is formed by appending the Interface Identifier, as defined above, to the prefix FE80::/64.

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

8. Unicast Address Mapping

The address resolution procedure for mapping IPv6 non-multicast addresses into MS/TP link-layer addresses follows the general description in Section 7.2 of [RFC4861], unless otherwise specified.

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 node 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: for Source Link-layer address.

2: for Target Link-layer address.

Length: This is the length of this option (including the type and length fields) in units of 8 octets. The value of this field is 1 for 8-bit MS/TP addresses.

MS/TP Address: The 8-bit address in canonical bit order [RFC2469].

This is the address the interface currently responds to.

9. Header Compression

LoBAC uses LOWPAN_IPHC IPv6 compression, which is specified in [I-D.ietf-6lowpan-hc] and included herein by reference. This section will simply identify substitutions that should be made when interpreting the text of [I-D.ietf-6lowpan-hc].

In general the following substitutions should be made:

* Replace "6LoWPAN network" with "MS/TP network"

* Replace "IEEE 802.15.4 address" with "MS/TP address"

Where 16-bit addresses are called for (e.g., a short IEEE 802.15.4 address) they MUST be formed by padding the MS/TP address to the left with a zero:

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     0x00      | MS/TP address |
+-+-+-+-+-+-+-+-+---------------+
```

10. IANA Considerations

This document uses values previously reserved by [RFC4944] and [I-D.ietf-6lowpan-hc] and makes no further requests of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

11. Security Considerations

The method of deriving Interface Identifiers from MAC addresses is intended to preserve global uniqueness when possible. However, there is no protection from duplication through accident or forgery.

12. Acknowledgments

Thanks are extended to the authors of [RFC4944] and members of the IETF 6LoWPAN working group; this document borrows extensively from their work.

13. References

13.1. Normative References

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