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Transmission of IPv6 Packets over WIA-PA Networks

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Abstract

This document describes an Internet Protocol Version 6 (IPv6) packet transmission scheme for Wireless Networks for Industrial Automation-Process Automation (WIA-PA) networks. According to the specific demands of WIA-PA networks, the document proposes the improved WIA-PA protocol stack architecture for IPv6 technology, and the transmission format of IPv6 packets for WIA-PA networks. Furthermore, based on the characteristics of WIA-PA networks, the IPv6 address auto-configuration method is also proposed.

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1. Introduction

It has been well known that Wireless Networks for Industrial Automation-Process Automation (WIA-PA) standard became the national standard of China, as well as the international standard approved by the International Electrotechnical Commission (IEC) in 2011. WIA-PA is an industrial wireless network standard towards industrial process automation, which consists of host, gateway, routing, field devices and handheld devices. WIA-PA networks have been widely used in factories, mines, smart home, intelligent transportation and all scenes related to the Internet of Things. Internet Protocol Version 6 (IPv6) is designed by Internet Engineering Task Force (IETF) with the advantage of high security, good mobility, address auto-configuration and abundant address resources. Recently, there has been a considerable interest in the transmission of IPv6 packets in industrial wireless sensor networks. For the research on the IPv6 key technologies and standards, IETF sets up the corresponding working groups. For instance, 6lo working group, which is devoted to applying IPv6 technology to resource-limited networks, and IPv6-based Low-power Personal Area Network (6LoWPAN) protocol has been the main standard of IPv6 application for wireless sensor networks.

There exists a trend to apply IP technology to field devices for industrial applications, without a doubt, it also meets the demand of market. In 2013, ZigBee Alliance published the ZigBee IP specification, which makes a great contribution to connecting wireless sensor networks to Internet seamlessly via IPv6 technology. The network layer of ISA100.11a standard published by Industry Subversive Alliance (ISA) International Society of Automation has been fully compatible with 6LowPAN technology. In addition, Highway Addressable Remote Transducer (HART) fund published Wireless HART standard, and introduced the latest HART function HART-IP in Hanover Industrial Fair in 2014. Nevertheless, in China, none of the key technology of WIA-PA standard is related to IPv6, and it is rare to discuss IPv6 for WIA-PA networks abroad. It is important to realize that through IPv6 technology, we can achieve the interconnection between WIA-PA networks and Internet. For the Internet, a variety of technologies and mature applications can be extended to WIA-PA networks directly, and for WIA-PA networks, we can extend the range of transmission among industrial devices to all over the world.

[RFC4944] has defined the transmission of IPv6 packets on IEEE 802.15.4. The WIA-PA standard based on IEEE 802.15.4 has been used extensively in industrial process measurement, monitoring and surveillance. In [RFC4944], IPv6 technology can be applied to support the transmission of IPv6 packets over WIA-PA networks.

The aim of this document is to introduce the IPv6 transmission over WIA-PA networks.

1.1. Requirements Notation

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. Terms Uesd

WIA-PA: ''Wireless Networks for Industrial Automation-Process Automation'', a Chinese industrial wireless specification, is passed by 96% of IEC(International Electrotechnical Commission) members, and formally released as IEC/PAS 62601 standard document.

IPv6: Internet Protocol Version 6

IEC: International Electrotechnical Commission

IETF: Internet Engineering Task Force

IEEE: Institute of Electrical and Electronic Engineers

6LoWPAN: IPv6-based Low-power Personal Area Network

ISA: Industry Subversive Alliance

HART: Highway Addressable Remote Transducer

OSI: Open System Interconnect Reference Model

MAC: Medium Access Control

TDMA: Time Division Multiple Access

CSMA: Carrier Sense Multiple Access

PANID: Personal Area Network ID

2. WIA-PA Standard

This section provides a brief overview of WIA-PA standard. We will introduce its network topology, protocol architecture and address types.

2.1. WIA-PA Network Topology

WIA-PA network topology SHOULD have two layers and it is a combination of star topology and mesh topology. The first layer is a MESH network, which is made up of gateways and routing nodes and can enhance robustness of WIA-PA networks. Moreover, WIA-PA networks also define redundancy gateways and redundancy routings, which enhances the reliability and self-healing capacity of the network. The second layer is a star network, which consists of routing nodes and field devices, and it is easy for network maintenance and management due to the relatively simple topology. And the WIA-PA network topology is shown in Figure 1.

```
                               Host
                                 |
                                 |
                                 |
                                 |
                 Node         Gateway         Node
                     \       /       \       /
                      \     /         \     /
                       Router         Router
                      /   |  \       /  |   \
                     /    |   \     /   |    \
                 Node     |    \   /    |      Node
                          |     \ /     |
                          |      /      |
                          |     / \     |
                 Node     |    /   \    |      Node
                     \    |   /     \   |    /
                      \   |  /       \  |   /
                       Router ------- Router-----------Handheld
                      /                     \
                     /                       \
                 Node                          Node
```

Figure 1: WIA-PA Network Topology

2.2. WIA-PA Protocol Architecture

WIA-PA network protocol follows OSI reference model, however, it only defines data link layer, network layer and application layer, physical layer and MAC layer are based on IEEE 802.15.4. And The WIA-PA network protocol stack is shown here:

```
------------+----------------------------------+
+----------------------------------------------+
            |    User Application Process     |  |    Device Management
Application Process   |
            +------------+   +----------------+  +-------------------+
+---------------------+
            |    User    |   |      User      |  |Network Management | |
Security Management |
            |Application |...|  Application   |  +-------------------+
+---------------------+
Application |  Object 1  |   |    Object n    |
|                                            |
            +------------+   +----------------+  |    +---------------
+                      |
            |        +-----------+            |  |    |
|                      |
   Layer    +--------+ ASLDE-SAP +------------+--+----+   ASLDE-SAP
+-------------+        |
            +--------+           +-------------------+
+-----------+ |        |
            |        +-----------+                    +---------------
+           | |        |
            +-------------+---------------+           +-----------+----------+
+-+-+-+       |
            |Communication| Polymerization |Application|Application|Management|
|ASLME|       |
            |             |      and       |           |   Layer   |          |
|     |       |
            |    Mode     |Depolymerization| Sublayer  |  Security | Services |
|-SAP |       |
            +-------------+---------------+           +-----------+----------+
+-+-+-+       |
            |        +----------+                     +-------------
+             | |        |
------------+--------+ NLDE-SAP +---------------------+  NLME-SAP
+-------------+ |        |
            +--------+          +--------------------+
+-------------+ |   + - + |
            |        +----------+                     +-------------
+             | |   |   | |
            +------------+---------+                  +-------------+----------
++-+-+-+ | M | |
  Network   | Addressing | Router  |  Network Layer   |Fragmentation|
Management||NMLE | |   | |
   Layer    +------------+---------+                  |     and     |
||     | | I | |
            |                                         |Restructuring| Services
||-SAP | |   | |
```

```
            +-------------------------------------------+-------------+----------
++-+-+-+ | B | |
            |        +----------+                     +--------------
+            | |    |    | |
            +--------+ DLDE-SAP +----------------------+   DLME-SAP
+------------+ |    |    | |
------------+--------+          +----------------------+
+------------+ |   + - + |
            |        +----------+                     +--------------
+            | |          |
            +---------------+----------+  Data  +--------+--------+-----------+
+-+-+-+       |
            |      Time     |Superframe|  Link  |  Hop  |  Link  | Management|
|DLME |       |
   Data     |Synchronization|Scheduling|Sublayer|Channel|  Layer |           |
|     |       |
   Link     +---------------+----------+        |       |Security|  Services |
|-SAP |       |
   Layer    |                                   +--------+--------+-----------+
+-+-+-+       |
            |        +----------+                     +--------------
+            | |          |
            +--------+ MLDE-SAP +----------------------+   MLME-SAP
+------------+ +---------+
            +--------+          +----------------------+
+------------+
            |        +----------+                     +--------------
+            |
            |                         IEEE 802.15.4 MAC
Layer                     |

|                                                                     |
------------
+---------------------------------------------------------------------+
  Physical
|                                                                     |
   Layer    |                      IEEE 802.15.4 Physical
Layer                   |
------------
+---------------------------------------------------------------------+
```

Figure 2: Protocol Architecture of WIA-PA Networks

2.3. Address Types of WIA-PA Networks

As for address types, in WIA-PA networks, all devices MUST have globally unique EUI-64 long addresses and 16-bit short addresses. Devices are assigned EUI-64 long addresses by manufacturers and 16-bit short addresses by host, and they communicate for one another with a short address.

3. Specification of IPv6 over WIA-PA Networks

In this section, we define the specification of IPv6 packets over WIA-PA networks.

WIA-PA standard has defined MESH router mechanism, aggregation/disaggregation and fragmentation/restructuring, thus for WIA-PA networks with IPv6 technology, we SHOULD NOT adopt the MESH router mechanism and the fragmentation/restructuring defined by 6LoWPAN. However, in [RFC4944] and [RFC6282], address compression and stateless address auto-configuration SHOULD be applied to WIA-PA networks.

3.1. Protocol Stack

The IPv6 over WIA-PA protocol stack is shown in Figure 3. The protocol stack contains application layer, transport layer, network layer, data link layer and physical layer, and the functions of each layer are as follows:

- Application layer: It defines the communication service to support the communications among a plurality of objects of distributed applications in industrial environment. For data communication service, it mainly includes three types of modes: client/server communication, publish/subscribe communication and report communication.

- Transport layer: It uses the connectionless and small footprint UDP protocol, and provides the service between network layer and application layer. Meanwhile, it also completes the encapsulation and parsing of UDP packets and the establishment and destruction of UDP connection.

- Network layer: It is divided into network layer upper and network layer lower, wherein the network layer upper is the Internet layer which consists of IP layer and adaptation layer. The main tasks of IP layer are IPv6 packets encapsulation, address resolution, and providing mobility support and stateless address auto-configuration, etc. IPv6 header compression mechanism and padding message values are

executed in adaptation layer. Network layer lower is WIA-PA network layer, which is mainly used for the network layer of WIA-PA standard. In addition, MESH subnet routing and addressing are also achieved in Network layer lower.

o Data link layer and physical layer: Both of them adopt the techniques of WIA-PA standard. Data link layer supports radio frequency (RF) channel access, and device network joining, etc. Physical layer is used for energy detection, channel selection, as well as starting and ending a RF transceiver.

```
--------------+-----------------------------------+
+---------------------------------------+
              |    User Application Process      |  |  Device Management
Application Process  |
              +-------------+   +---------------+  +-------------------+
+-------------------+
              |    User     |   |     User       |  |Network Management | |
Security Management|
              |Application  |...|  Application   |  +-------------------+
+-------------------+
Application   |  Object 1   |   |   Object n     |
|                                         |
              +-------------+---+---------------+--+------------+----------
+----------+     |
    Layer     |Communication|   | Polymerization |  Application  |Application|
Management|     |
              |             |   |      and       |               |   Layer
|          |     |
              |    Mode     |   |Depolymerization|   Sublayer    |  Security |
Services |     |
--------------+-------------+---+---------------+---------------+----------
+----------+     |
 Transport
|                                                                        |
|
   Layer      |       UDP                 Transport
Layer                             |     |
--------------
+-----------------------------------------------------------------------+  M
|
Internet
Layer|
|     |
/Network Layer+-----------------------+                  +------------
+------------------+     |
    Upper     |Address Configuration |     IP Layer     |  Address   |
Adaptation   |  I  |
```

```
              +----------------------+                  |Compression |
Layer      |     |
Network       |                                         +------------
+                   |     |
 Layer -------+------------------------------------------
+------------------------------+  B  |
              +--------------------+                       +----------------
+-----------+     |
WIA-PA Network| Management Services| WIA-PA Network Layer  |  Fragmentation |
Router   |     |
Layer/Network +--------------------+                       | /Restructuring
|           |     |
Layer Lower   |                                            +----------------
+-----------+     |
--------------+---------------+----------+-------------+-------+--------
+-----------+---+     |
              |      Time     |Superframe|    Data     |  Hop  |  Link  |
Management|   |     |
   Data       |Synchronization|Scheduling|    Link     |Channel|  Layer
|           |   |     |
   Link       +---------------+----------+  Sublayer   |       |Security|
Services |   |     |
   Layer      |                                        +-------+--------
+-----------+   |     |

+---------------------------------------------------------------------------+
|
              |                         IEEE 802.15.4 MAC
Layer                      |     |
--------------
+---------------------------------------------------------------------------+
|
Physical Layer|                      IEEE 802.15.4 Physical
Layer                    |     |
--------------
+--------------------------------------------------------------------------
+------+
```

Figure 3: IPv6 over WIA-PA Protocol Stack

3.2. Network Layer Frame Format

In order to introduce IPv6 technology to WIA-PA networks, we combine WIA-PA standard and IPv6 technology, adding Internet layer and transport layer to previous WIA-PA network protocol stack, where adaptation layer and IP layer MUST be included in Internet layer.

3.2.1. Network Layer Frame Format

The WIA-PA network frame format with IPv6 technology is shown in Figure 4. If the command frames interact with each other, the frame format SHOULD NOT include Internet layer, transport layer and application layer, and if the IPv6 packets interact for one another, the frame format for IPv6 packets is as follows:

```
+-------+-----------+--------------------+-------------+---------
+--------------------+----+
|  MAC  |Data Link  |       WIA-PA       |   Internet   |Transport|
Application     |    |
| Layer |  Layer    |   Network Layer    |     Layer    | Layer   |
Layer         |Load|
| Header|  Header   |       Header       |    Header    | Header  |
Header       |    |
+-------+-----------+--------------------+-------+------+---------+-------
+------+------+----+
|       |           |Network Frame Control|       |      |         |
|      |      |    |
|       |           +-------+-------------+       |      |         |
|      |      |    |
|       |           |       | Destination |       |      |         |
|      |      |    |
|       |           |       |   Address   |       |      |         |
|      |      |    |
|Source |Destination| Router+-------------+Message| Other|   UDP   |  APS  |
Serial|Frame |Load|
|Address|  Address  | Field |   Source    |Values |Fields|  Header | Frame |
Number|Length|    |
|       |           |       |   Address   |       |      |         |
Control|      |      |    |
|       |           |       +-------------+       |      |         |
|      |      |    |
|       |           |       |  Router ID  |       |      |         |
|      |      |    |
|       |           +-------+-------------+       |      |         |
|      |      |    |
|       |           |    Other Fields     |       |      |         |
|      |      |    |
+-------+-----------+--------------------+-------+------+---------+-------
```

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

Figure 4: IPv6 over WIA-PA Frame Format

The IPv6 packets make a modification on the frame control field of WIA-PA network layer header, which mainly defines bit5 of the frame control field. When bit5 is equal to 0, it indicates the packet MUST be a protocol data unit of WIA-PA network layer, and when bit5 is equal to 1, if package type is a WIA-PA network layer command frame, it indicates the packet MUST be an IPv6 related command frame, and if package type is a WIA-PA network layer packet, it indicates the packet MUST be an IPv6 packet then passes it to the upper layer to resolve. The revised WIA-PA network layer frame control field is shown in Figure 5.

```
   +-----------+-----------------+-----------+----------------+---------------
+--------------+
   |Bit:  0-1  |        2        |     3     |       4        |       5
|     6-7      |
   +-----------+-----------------+-----------+----------------+---------------
+--------------+
   |   Packet  | Fragmentation   |    P/S    |  Certification |  IPv6 Packet
|   Retention  |
   |    Type   |      Flag       |    Flag   |      Flag      |     Flag
|              |
   +-----------+-----------------+-----------+----------------+---------------
+--------------+
```

Figure 5: Network Layer Frame Control Field

3.2.2. Network Layer Command Frame

In order to solve the problem of nodes getting the network prefix or IPv6 address, our document defines the following five categories of IPv6 network layer command frame:

1) Enhanced IPv6 joining response command frame: The command identifier is defined as ''129'', and it SHOULD be used for IPv6 nodes to reply the access network request. Network layer frame format of the response is shown in Figure 6. According to the ways to distribute IPv6 addresses or prefixes by host, the values of response command frame related field to be different.

```
+--------
+-------------------------------------------------------------------------------------
+
|
Network|
|
| Layer |                                 Network Layer
Load                                  |
|
Header|
|
+--------+----------+-----+------------------+--------------
+--------------------+------------+
|       |          |     | Physical Address | Short Address| IPv6 Address
Option |            |
| Header|  Command |Added|    of Devices    |  of Devices  |    of
Devices       |IPv6 Address|
|       |Identifier|State|    to be added   |  to be added |   to be
added       |   /Prefix  |
+--------+----------+-----+------------------+--------------
+--------------------+------------+
```

Figure 6: Enhanced IPv6 Joining Response Command Frame

2) Query short address request command frame: The command identifier is defined as ''130'', and the packet SHOULD be used for devices to query their own short addresses according to IPv6 addresses. Its frame format is shown here:

```
         +-------------------------+-------------------------------------------
+
         |   Network Layer Header |             Network Layer Load
|
         +-------------------------+-----------------------+--------------------
+
         |         Header          |   Command Identifier  |    IPv6 Address
|
         +-------------------------+-----------------------+--------------------
+
```

Figure 7: Query Short Address Request Command Frame

3) Query short address response command frame: The command identifier is

defined as ''131'', and the packet SHOULD be used for host to send a short address query request result to devices. Its frame format is shown here:

```
   +----------------------
+---------------------------------------------------------------------+
   | Network Layer Header |                         Network Layer
Load                         |
   +----------------------+------------------+--------------------+------------
+---------------+
   |        Header        |Command Identifier| Execution Results |IPv6 Address|
Short Address |
   +----------------------+------------------+--------------------+------------
+---------------+
```

Figure 8: Query Short Address Response Command Frame

4)   Query IPv6 address request command frame: The command identifier is defined as ''132'', and the packet SHOULD be used for devices to query IPv6 addresses according to their own short addresses. Its frame format is shown here:

```
         +-------------------------+--------------------------------------------
+
         |   Network Layer Header |             Network Layer Load
|
         +-------------------------+------------------------+--------------------
+
         |         Header          |   Command Identifier  |    Short Address
|
         +-------------------------+------------------------+--------------------
+
```

Figure 9: Query IPv6 Address Request Command Frame

5)   Query IPv6 address response command frame: The command identifier is defined as ''133'', and the packet SHOULD be used for host to send an IPv6 address query request result to devices. Its frame format is shown here

```
   +----------------------
+---------------------------------------------------------------------+
   | Network Layer Header |                          Network Layer
Load                        |
   +----------------------+------------------+--------------------+-------------
+--------------+
   |         Header       |Command Identifier| Execution Results |Short
Address| IPv6 Address |
```

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

Figure 10: Query IPv6 Address Response Command Frame

3.2.3. Transmission Format of IPv6 Packets

For the transmission of IPv6 packets, our document combines 6LoWPAN address compression method and the ways to obtain IPv6 address to define the following four kinds of header format of Internet layer, and the format of Internet layer header is shown here:

```
    +-------+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
+--------------------+
    |Bit: 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 |
Lengthen      |
    +-------+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
+--------------------+
    |      FLAG     |   TF   | NH| HLIM  |CID|SAC|  SAM  | M |DAC|  DAM
|                    |
    +---------------+-------+---+-------+---+---+-------+---+---+-------+
Other Fields   |
    |              Dispatch             |        IPHC Basic Coding
|                    |
    +-----------------------------------+------------------------------
+--------------------+
```

Figure 11: Internet Layer Header Format

The Internet layer headers of IPv6 packets have different dispatch due to the devices use different ways to get IPv6 address. And the four different types of dispatch mentioned above are as follows:

1) If the devices communicate with extranet devices, we SHOULD use uncompressed IPv6 packets during transmission, then the Internet layer header contains dispatch and other fields, where the dispatch is ''01000001'' and other fields are the related fields of IPv6 header.

2) If the IPv6 address prefix of devices is the entire network unified prefix, the IPv6 packets are stateless compression. In this case, the Internet layer header only contains dispatch and address compression coding with the value of ''011TT1HH00110011'', where the value of ''TT'' represents IPv6 header compression about Traffic Class, and the value of ''HH'' represents IPv6 header compression about Hop Limit.

3) If is not the entire network unified prefix, the IPv6 packets are state compression, and the Internet layer header also includes dispatch and the address compression coding with the value of ''0111111001110111''.

4) If the devices use the IPv6 header compression algorithm of 6LoWPAN to partially compress IPv6 header, the Internet layer header contains dispatch, address compression coding and other fields, where other fields are the uncompressed part of IPv6 header.

3.3. Stateless Address Auto-Configuration Scheme

All devices SHOULD be distributed prefixes or IPv6 addresses by host, and the process modes of devices are different due to the various distribution ways. There are three approaches as follows:

1) Unified network prefix: Host distributes a unified whole network prefix to each device, and the devices can generate IPv6 addresses with address configuration method. Then, we have the following four categories of IPv6 address:

o The automatically generated IPv6 link-local address in the process of device initialization: The IPv6 link-local address SHOULD be composed by prefix and interface identifier, where the prefix is ''FE80::0'', and the interface identifier is the negation of bit7 of EUI-64 physical address. The EUI-64 link-local address is shown here:

```
         +------------------------+-----------------------+--------------------
+
         |        Bit: 1-10       |         11-64         |        65-128
|
         +------------------------+-----------------------+--------------------
+
         |       1111111010       |           0           |        EUI-64
|
         +------------------------+-----------------------+--------------------
+
```

Figure 12: EUI-64 Link-local Address

o The IPv6 link-local address generated by the short address distributed by gateway: The prefix is ''FE80::0'', the interface identifier is generated by the short address and the negation of bit7 of PANID. Due to the addresses are all composed by prefix and interface identifier, only difference in composition, no more reiteration here. The short address link-local address is shown here:

```
   +-----------+-------+---------+---------+------------------+---------
+---------------------+
   | Bit: 1-10 | 11-64 |  65-80  |  81-88  |      89-104      | 105-112 |
113-128       |
   +-----------+-------+---------+---------+------------------+---------
+---------------------+
   | 1111111010|   0   |  PANID  |    0    | 1111111111111110 |    0    |16-bit
Short Address |
   +-----------+-------+---------+---------+------------------+---------
+---------------------+
```

Figure 13: Short Address Link-local Address

o The IPv6 unicast address generated by the unified whole network prefix distributed by host and EUI-64 physical address: The prefix is a unified whole network prefix distributed by host, the interface identifier is the negation of bit7 of EUI-64 physical address, and the EUI-64 unicast address is shown in Figure 14, where N is the prefix length.

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

```
         |       Bit: 1-N        |         64-N           |        65-128
|
         +-----------------------+-----------------------+--------------------
+
         |        Prefix         |           0            |        EUI-64
|
         +-----------------------+-----------------------+--------------------
+
```

Figure 14: EUI-64 Unicast Address

o The IPv6 unicast address generated by the unified whole network prefix distributed by host and the short address distributed by gateway: The prefix is a unified whole network prefix distributed by host, the interface identifier is generated by the short address and the negation of bit7 of PANID, and the short address unicast address is shown here:

Bit: 1-N	64-N	65-80	81-88	89-104	105-112	113-128
Prefix	0	PANID	0	1111111111111110	0	16-bit Short Address

Figure 15: Short Address Unicast Address

2) Non-Unified network prefix: Host distributes the entire network non-uniform prefix to devices, through the prefix, devices can generate IPv6 address with address configuration method. Consequently, it can also generate four kinds of IPv6 address, and the way is consistent with the unified one.

3) IPv6 address: Host distributes IPv6 address to devices. Then, two kinds of IPv6 address can be generated, one is the IPv6 address distributed by host, the other is the IPv6 link-local address generated by EUI-64 physical address, as shown in figure 12.

3.4. Multicast Address Conversion Method

In WIA-PA networks, there MUST be two types of address: EUI-64 long address and 16-bit short address. In order to achieve the conversion between WIA-PA network address and IPv6 network address, for EUI-64 long address, we complete the conversion with the use of address configuration method in [RFC4944]. And the short address is divided into broadcast address and unicast address, the unicast address uses the address configuration method in [RFC4944], the definition of broadcast address is according to the broadcast address set by WIA-PA standard and the structural properties of IPv6 multicast address. Several types of WIA-PA broadcast address are shown here:

Broadcast Address Types	Broadcast Address within the Cluster	The Whole Network Broadcast Address	MESH Network Broadcast Address	Gateway Broadcast Address

```
+-----------------+
   |  Broadcast  |Cluster Address x.25 |     255.255     |      255.0
|      0.255      |
   |  Addresses  |   x Range: 1-254    |                 |
|                 |
   +-------------+---------------------+-----------------+-----------------
+-----------------+
```

Figure 16: WIA-PA Broadcast Address

The IPv6 multicast address is shown in Figure 17. In [RFC4291], IPv6 multicast address defines its top eight is ''11111111''. Besides, the second field is a flag field, it is permanent when the multicast address is ''0000'', and it is temporary when ''0001''. The third field is a range field, the different values represent the different range. The broadcast address of our document is only for devices in link-local, and the range field indicates link-local when it is ''0010''.

Bit: 0-7	8-11	12-15	16-128
11111111	Flags	Scope	Group ID

Figure 17: IPv6 Multicast Address

As shown in Figure 18, we define IPv6 broadcast address for WIA-PA networks, where the broadcast address within the cluster is ''FF12::x .FF''. Due to the broadcast address within the cluster is non-permanent distribution, thus its flag field is ''1'', and ''x'' indicates the cluster address of network, which is located in ''1-254''. In addition, the broadcast address of entire network is ''FF02::1'', which represents all field devices from broadcast to network. The broadcast address of MESH network is ''FF02::2'', which represents all routers from broadcast to network, and the broadcast address of gateway is ''FF02::FF''.

Broadcast Address Types	Broadcast Address within the Cluster	The Whole Network Broadcast Address	MESH Network Broadcast Address	Gateway Broadcast Address
WIA-PA Network IPv6 Broadcast	FF12::x. FF x Range: 1-254	FF02::1	FF02::2	FF02::FF

Figure 18: IPv6 Broadcast Address

4. IANA Considerations

There are no IANA considerations related to this document.

5. Security Considerations

In industrial environment, the wireless networks share the same place and time. In this case, if the security mechanism is not very brilliant, it will seriously affect the system's information security. The security mechanism is beyond the scope of this draft.

6. Conclusions

This document proposed a scheme which is suitable for the transmission of IPv6 packets over WIA-PA networks. Protocol architecture, IPv6 specific command frame, the transmission format of packets in adaptation layer and multicast address conversion method are all defined in this document.

7. Acknowledgments

We are grateful to the authors of [RFC4944] and [RFC6282] and the members of the IETF 6LoWPAN working group.

8. References

8.1. Normative References

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