6Lo Working Group
Internet Draft
Interned status: Standards Track
Expires: September 25, 2015

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March 24, 2015

Transmission of IPv6 Packets over WIA-PA Networks

draft-wang-6lo-wiapa-02

Abstract

This document describes the frame format and address configuration for transmission of IPv6 packets on WIA-PA (Wireless networks for Industrial Automation-Process Automation) networks. WIA-PA is approved by IEC (the International Electrotechnical Commission) as an international standard for industrial wireless networks with the designation IEC 62601. The document also describes the protocol architecture and necessary command frames for supporting IPv6 protocol in WIA-PA networks.

Status of this Memo

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1. Introduction

WIA-PA (Wireless networks for Industrial Automation-Process Automation) is an industrial wireless network standard toward industrial process automation. The WIA-PA network consists of five categories physical devices: Host, gateway, router, field devices and handheld devices. Currently, WIA-PA networks have been widely used in factories, mines as well as Smart Home, Intelligent Transportation and all scenarios related to the Internet of Things.

IPv6 protocol as the core protocol of the Internet of Things has the advantages of high security, high mobility, address auto-configuration and abundant address resources. It is an important trend that IP technology will be applied to wireless sensor nodes and network architecture for meeting the requirements of wireless sensor networks. In addition, we can achieve the interconnection between WIA-PA networks and Internet by means of IPv6 technology. In terms of the Internet, a variety of technologies and mature applications can be extended to WIA-PA networks, and for WIA-PA networks, we can extend the range of transmission among objects to the whole human society even around 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

IEEE: Institute of Electrical and Electronic Engineers

OSI: Open System Interconnect Reference Model

MAC: Medium Access Control

TDMA: Time Division Multiple Access

CSMA: Carrier Sense Multiple Access

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

PANID: Personal Area Network ID

2. WIA-PA Standard

This section provides a brief overview of WIA-PA standard.

WIA-PA standard was published as People's Republic of China national standard GB/T 26790.1-2011 in July 2011. Then in October 2011, voted by all members of IEC, it becomes the international standard IEC: IEC62601Ed.1. What is worth mentioning that gateways, routers and field devices use the WIA-PA standard GB/T 26790.1, besides, WIA-PA standard can also be used in computers, handheld devices, etc.

2.1. WIA-PA Protocol Stack

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. Physical layer SHOULD be used for energy detection, channel selection, and both sending and receiving data. Data link layer mainly ensures reliable, secure, accurate and real-time transmission from device to device. Besides, it supports hopping mechanism, retransmission mechanism, TDMA and CSMA mixing channel access mechanism. Network layer not only manages the whole network, configuring and controlling the operation of its own, but also provides an interface to send and receive data for application layer. WIA-PA application layer is divided into user application process and application sublayer, and also defines the user application object and communication service, where the user application object SHOULD be applied to industrial process interaction, and the communication service supports the communication among a plurality of objects of distributed applications in industrial environment. The WIA-PA network protocol stack is shown here:

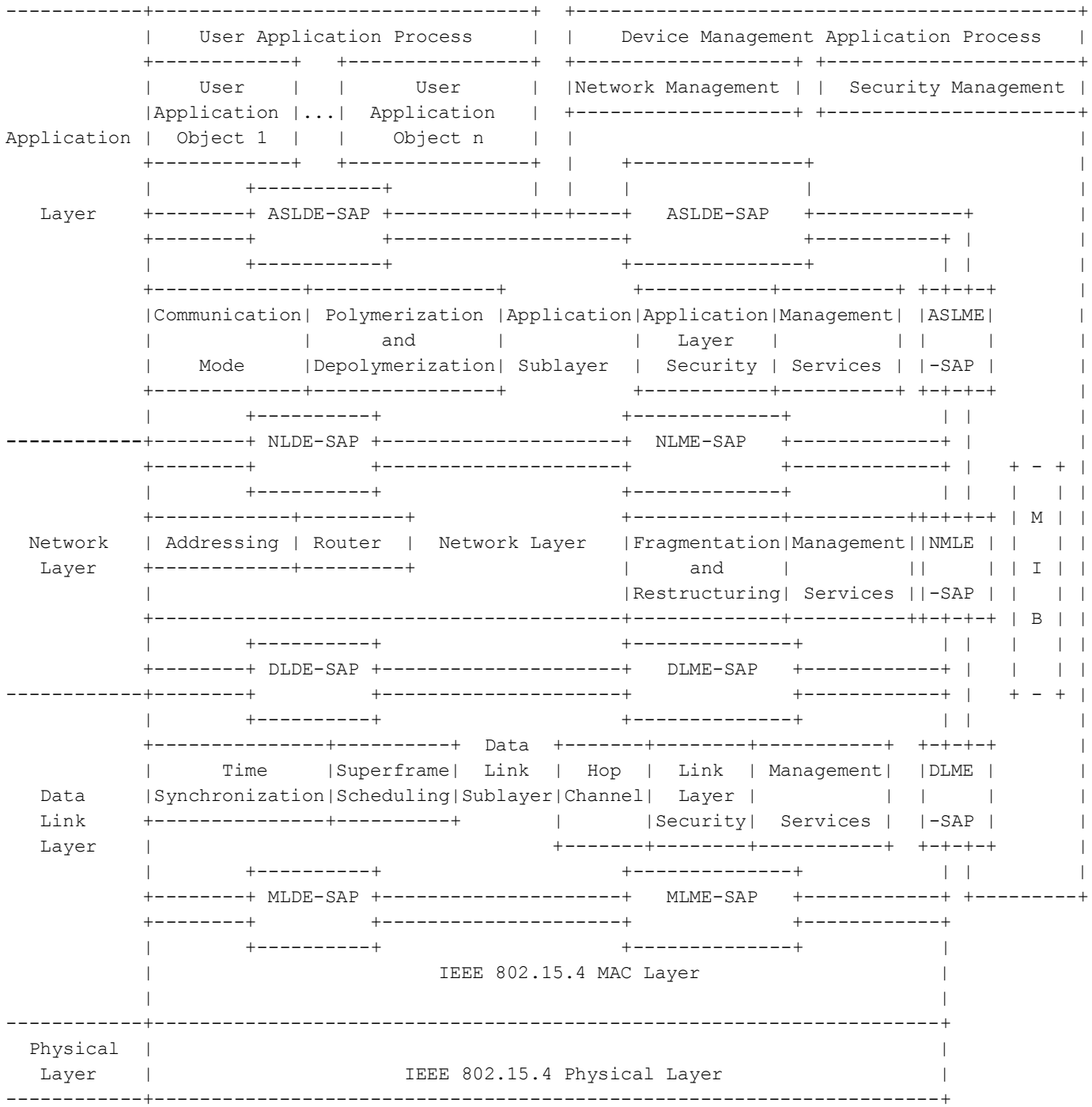

Figure 1: Protocol Stack of WIA-PA Networks

2.2. WIA-PA Network Topology

WIA-PA network topology SHOULD be two layers, combining star topology and mesh topology. The first layer is a MESH network that is made up of gateways and router nodes, which can enhance robustness of the entire network. Furthermore, WIA-PA networks also define redundancy gateways and redundancy routers, enhancing the reliability and self-healing capacity of the entire network. The second layer is a star network consisting of routers and field devices, which is very easy to be managed due to the relative simplicity of the topology. And the WIA-PA network topology is shown in Figure 2.

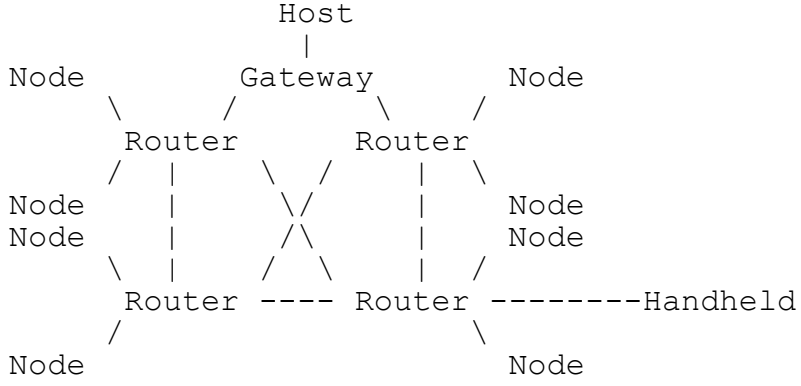

Figure 2: WIA-PA Network Topology

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

Transport layer uses the UDP protocol with connectionless, unreliable and small footprint. Internet is in the upper layer of WIA-PA network layer, and consisting of IP layer and adaptation layer. The IPv6 over WIA-PA protocol stack is shown in Figure 3.

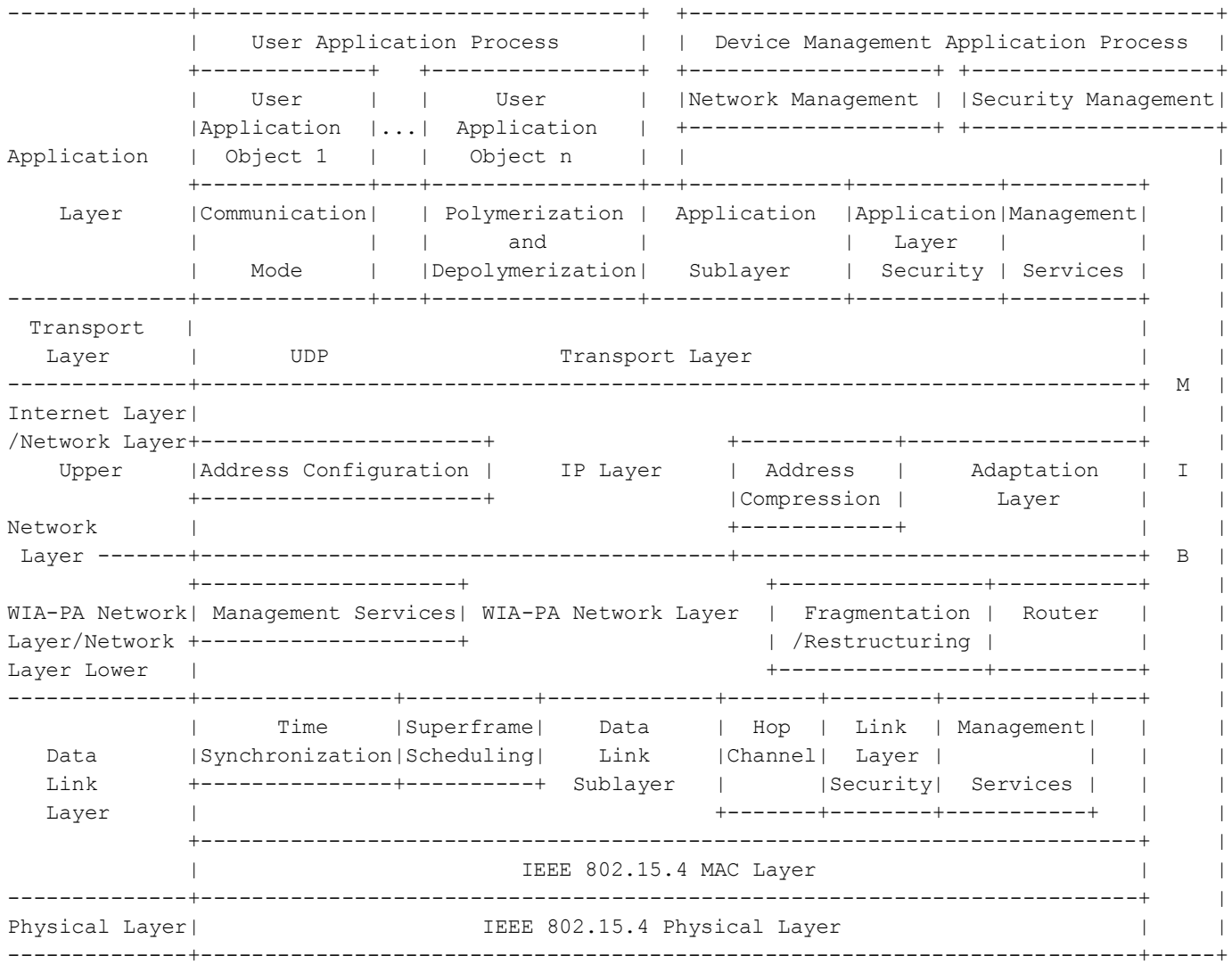

Figure 3: IPv6 over WIA-PA Protocol Stack

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. Simultaneously, considering WIA-PA network layer has realized fragmentation/restructuring and subnet MESH router, thus the network layer frame format SHOULD NOT include the MESH head and the fragmentation head of 6LoWPAN. 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:

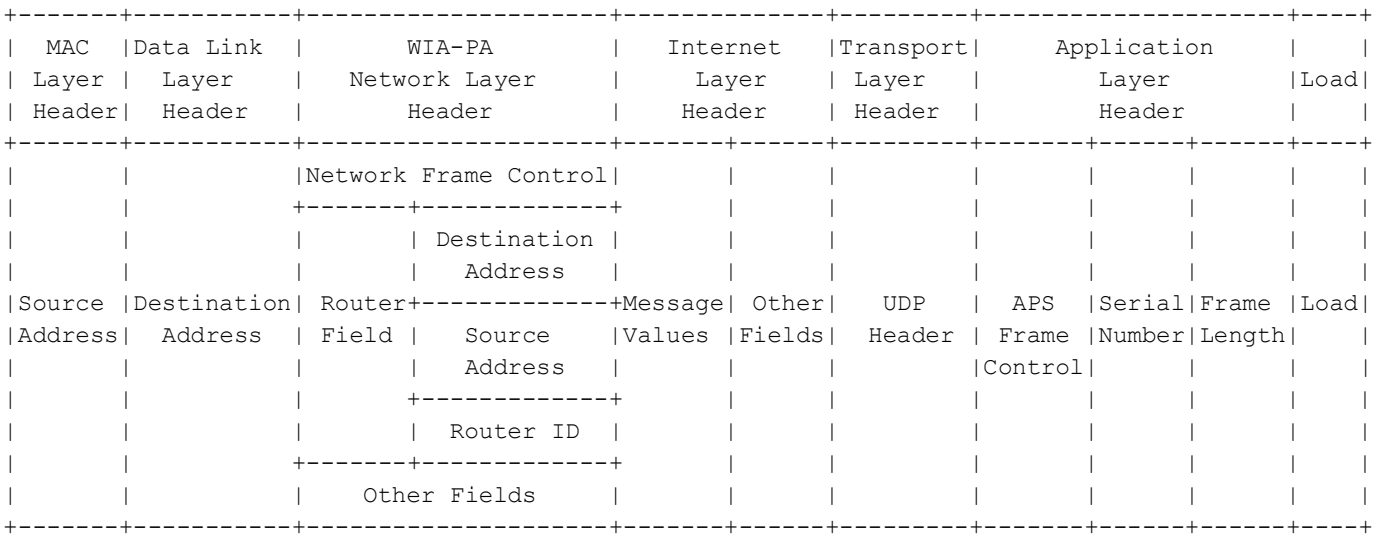

Figure 4: IPv6 over WIA-PA Frame Format

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.

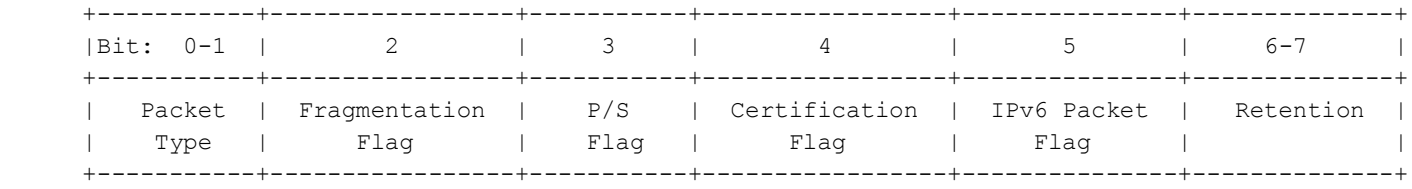

Figure 5: Network Layer Frame Control Field

3.3. Network Layer Command Frame

For mentioned above, when bit5 is equal to 1 and the packet type of frame control field is command frame, which means the packet MUST be an IPv6 network layer command frame. Our document defines the following five categories of IPv6 network layer command frame:

1) IPv6 enhanced joining response command frame: 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.

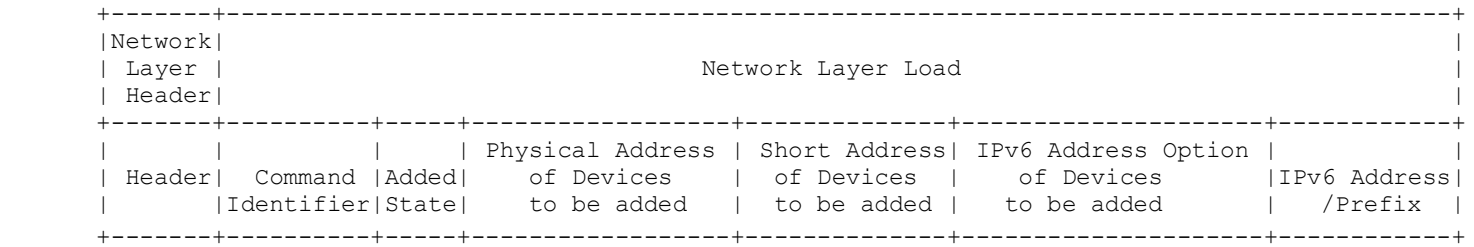

Figure 6: IPv6 Enhanced Joining Response Command Frame

2) Query short address request command frame: 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:

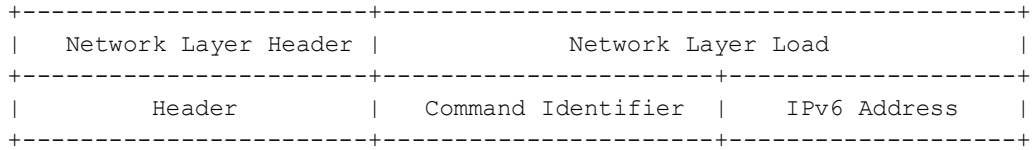

Figure 7: Query Short Address Request Command Frame

3) Query short address response command frame: 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:

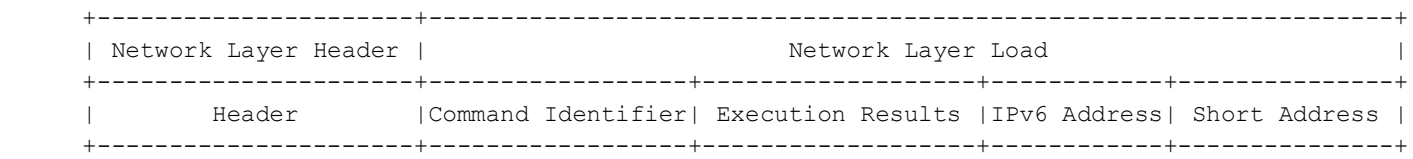

Figure 8: Query Short Address Response Command Frame

4) Query IPv6 address request command frame: 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:

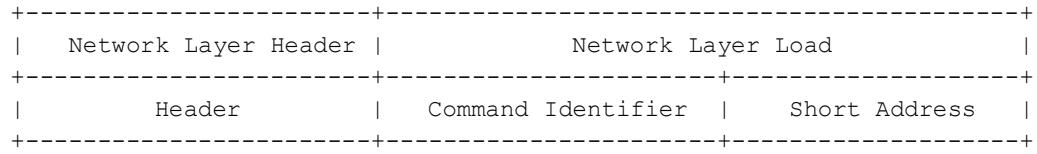

Figure 9: Query IPv6 Address Request Command Frame

5) Query IPv6 address response command frame: 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:

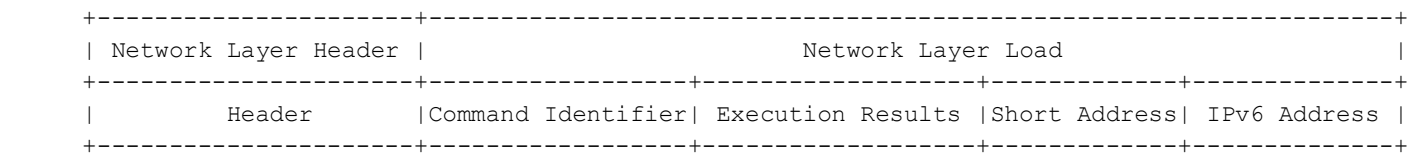

Figure 10: Query IPv6 Address Response Command Frame

3.4. Stateless Address Configuration

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) 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:

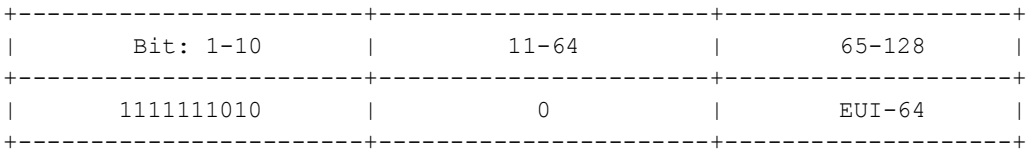

Figure 11: EUI-64 Link-local Address

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:

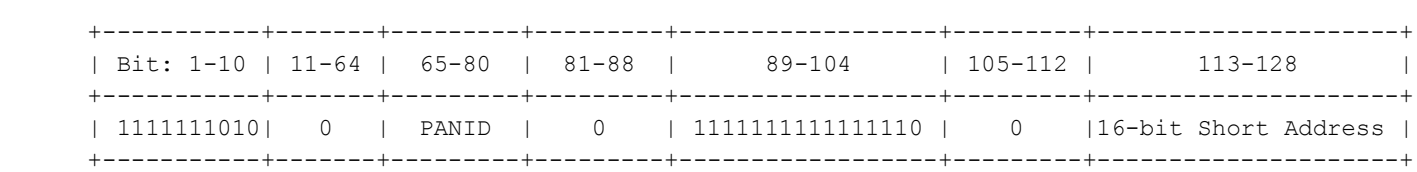

Figure 12: Short Address Link-local Address

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 13, where N is the prefix length.

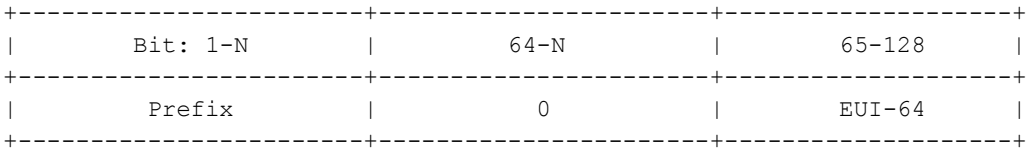

Figure 13: EUI-64 Unicast Address

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:

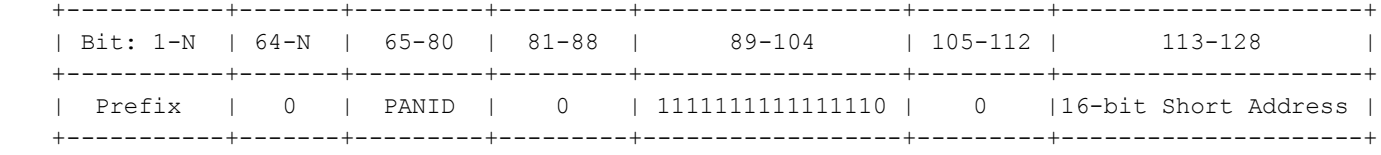

Figure 14: Short Address Unicast Address

2) 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) 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 11.

3.5. Transmission Format of IPv6 Packets

When bit5 is equal to 1, according to the packet types of frame control field, the packets of network layer can be divided into IPv6 network layer command frames and IPv6 packets. Therefore, 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 common format of Internet layer header is shown here:

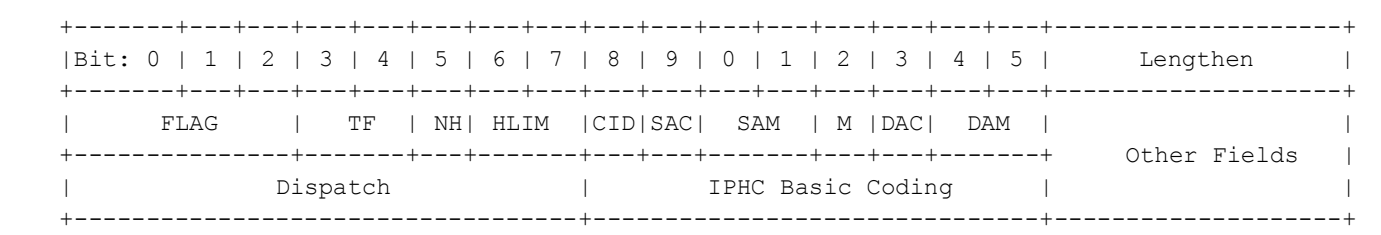

Figure 15: Internet Layer Header Common Format

The Internet layer headers of IPv6 packets have different dispatch due to the devices use different ways to get IPv6 address. What's

more, 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.

3.6. 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 Addresses	Cluster Address x.25 x Range: 1-254	255.255	255.0	0.255

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 describes the details of IPv6 transmission over WIA-PA networks. We add Internet layer and transport layer to WIA-PA protocol stack. According to the types of IPv6 packets, we redefine the frame format of network layer. Furthermore, the transmission format of packets in adaptation layer and multicast address conversion method are also 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

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", RFC 4291, February 2006.

[RFC4944] Montenegro, G., Kushalnagar, N., Hui, J., and Culler, D., "Transmission of IPv6 Packets over IEEE 802.15.4 Networks", RFC 4944, September 2007.

[RFC6282] J. Hui, Ed, "Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks", RFC 6282, September 2011.

8.2. Informative References

[EUI-64] IEEE, "GUIIDELINES FOR 64-BIT GLOBAL IDENTIFIER (EUI-64) REGISTRATION AUTHORITY", IEEE Std http://standards.ieee.org/regauth/oui/tutorials/EUI64.html, November 2012.

[I-D.ietf-6lo-btle] Nieminen, J., Savolainen, T., Isomaki, M., Patil, B., Shelby, Z., and C. Gomez, "Transmission of IPv6 Packets over BLUETOOTH Low Energy", draft-ietf-6lo-btle-00 (work in progress), November 2013.

8.3. External Informative References

[WIA-PA] IEC/PAS 62601 Ed.1.0[S], WIA-PA communication network and communication profile, 2009.

[ISA100.11a] ISA100.11a Working Group,”Wireless systems for industrial automation: Process control and related applications,” ISA100.11a Draft standard, September 2008.

[IEEE802.15.4] IEEE Computer Society, "IEEE Std. 802.15.4-2006", June 2006.

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