

Workgroup: 6Lo Working Group

Internet-Draft: draft-ietf-6lo-nfc-22

Published: 6 March 2023

Intended Status: Standards Track

Expires: 7 September 2023

Authors: Y. Choi, Ed. Y-G. Hong J-S. Youn

ETRI

Daejeon Univ

Donggeui Univ

Transmission of IPv6 Packets over Near Field Communication

Abstract

Near Field Communication (NFC) is a set of standards for smartphones and portable devices to establish radio communication with each other by touching them together or bringing them into proximity, usually no more than 10 cm apart. NFC standards cover communications protocols and data exchange formats, and are based on existing radio-frequency identification (RFID) standards including ISO/IEC 14443 and FeliCa. The standards include ISO/IEC 18092 and those defined by the NFC Forum. The NFC technology has been widely implemented and available in mobile phones, laptop computers, and many other devices. This document describes how IPv6 is transmitted over NFC using 6LoWPAN techniques.

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1. Introduction

NFC is a set of short-range wireless technologies, typically requiring a distance between sender and receiver of 10 cm or less. NFC operates at 13.56 MHz, and at rates ranging from 106 kbps to 424 kbps, as per the ISO/IEC 18000-3 air interface [[ECMA-340](#)]. NFC builds upon RFID systems by allowing two-way communication between endpoints. NFC always involves an initiator and a target; the initiator actively generates an RF field that can power a passive target. This enables NFC targets to take very simple form factors, such as tags, stickers, key fobs, or cards, while avoiding the need for batteries. NFC peer-to-peer communication is possible, provided that both devices are powered.

NFC has its very short transmission range of 10 cm or less, so the other hidden NFC devices behind outside the range cannot receive NFC signals. Therefore, NFC often regarded as a secure communications technology.

In order to benefit from Internet connectivity, it is desirable for NFC-enabled devices to support IPv6, considering its large address space, along with tools for unattended operation, among other advantages. This document specifies how IPv6 is supported over NFC by using IPv6 over Low-power Wireless Personal Area Network (6LoWPAN) techniques [RFC4944], [RFC6282], [RFC6775]. 6LoWPAN is suitable, considering that it was designed to support IPv6 over IEEE 802.15.4 networks [[IEEE802.15.4](#)], and some of the characteristics of the latter are similar to those of NFC.

2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

This specification requires readers to be familiar with all the terms and concepts that are discussed in "IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals" [[RFC4919](#)], "Transmission of IPv6 Packets over IEEE 802.15.4 Networks" [[RFC4944](#)], "Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)" [[RFC6775](#)].

6LoWPAN Node (6LN):

A 6LoWPAN node is any host or router participating in a LoWPAN. This term is used when referring to situations in which either a host or router can play the role described.

6LoWPAN Router (6LR):

An intermediate router in the LoWPAN that is able to send and receive Router Advertisements (RAs) and Router Solicitations (RSs) as well as forward and route IPv6 packets. 6LoWPAN routers are present only in route-over topologies.

6LoWPAN Border Router (6LBR):

A border router located at the junction of separate 6LoWPAN networks or between a 6LoWPAN network and another IP network. There may be one or more 6LBRs at the 6LoWPAN network boundary. A 6LBR is the responsible authority for IPv6 prefix

propagation for the 6LoWPAN network it is serving. An isolated LoWPAN also contains a 6LBR in the network, which provides the prefix(es) for the isolated network.

3. Overview of Near Field Communication Technology

This section presents an overview of NFC, focusing on the characteristics of NFC that are most relevant for supporting IPv6.

NFC enables simple, two-way, interaction between two devices, allowing users to perform contactless transactions, access digital content, and connect electronic devices with a single touch. NFC utilizes key elements in existing standards for contactless card Technology, such as ISO/IEC 14443 A&B and JIS-X 6319-4. NFC allows devices to share information at a distance up to 10 cm with a maximum physical layer bit rate of 424 kbps.

3.1. Peer-to-peer Mode of NFC

NFC defines three modes of operation: card emulation, peer-to-peer, and reader/writer. Only the peer-to-peer mode allows two NFC-enabled devices to communicate with each other to exchange information bidirectionally. The other two modes do not support two-way communications between two devices. Therefore, the peer-to-peer mode MUST be used for IPv6 over NFC.

3.2. Protocol Stack of NFC

NFC defines a protocol stack for the peer-to-peer mode ([Figure 1](#)). The peer-to-peer mode is offered by the Activities Digital Protocol at the NFC Physical Layer. The NFC Logical Link Layer comprises the Logical Link Control Protocol (LLCP), and when IPv6 is used over NFC, it also includes an IPv6-LLCP Binding. IPv6 and its underlying adaptation Layer (i.e., IPv6-over-NFC adaptation layer) are placed directly on the top of the IPv6-LLCP Binding. An IPv6 datagram is transmitted by the Logical Link Control Protocol (LLCP) with guaranteed delivery, two-way transmission of information between the peer devices.

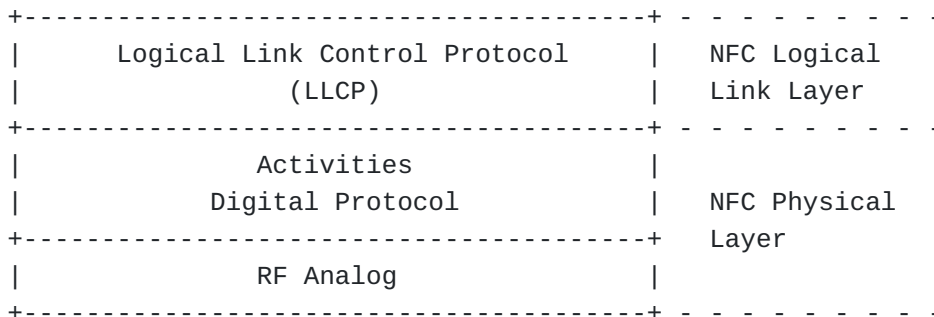


Figure 1: Protocol Stack of NFC

The LLCP consists of Logical Link Control (LLC) and MAC Mapping. The MAC Mapping integrates an existing RF protocol into the LLCP architecture. The LLC contains three components (Link Management, Connection-oriented Transmission, and Connectionless Transmission). The Link Management is responsible for serializing all connection-oriented and connectionless LLC PDU (Protocol Data Unit) exchanges and for aggregation and disaggregation of small PDUs. The Connection-oriented Transmission is responsible for maintaining all connection-oriented data exchanges including connection set-up and termination. However, NFC links do not guarantee perfect wireless link quality, so some type of delays or variation in delay would be expected in any case. The Connectionless Transmission is responsible for handling unacknowledged data exchanges.

In order to send an IPv6 packet over NFC, the packet MUST be passed down to the LLCP layer of NFC and carried by an Information Field in an LLCP Protocol Data Unit (I PDU). The LLCP does not support fragmentation and reassembly. For IPv6 addressing or address configuration, the LLCP MUST provide related information, such as link layer addresses, to its upper layer. The LLCP to IPv6 protocol binding MUST transfer the Source Service Access Point (SSAP) and Destination Service Access Point (DSAP) value to the IPv6 over NFC adaptation layer. SSAP is a Logical Link Control (LLC) address of the source NFC-enabled device with a size of 6 bits, while DSAP means an LLC address of the destination NFC-enabled device. Thus, SSAP is a source address, and DSAP is a destination address.

In addition, NFC links and host do not need to consider IP header bits for QoS signaling, or utilize these meaningfully.

3.3. NFC-enabled Device Addressing

According to [[LLCP-1.4](#)], NFC-enabled devices have two types of 6-bit addresses (i.e., SSAP and DSAP) to identify service access points. Several service access points can be installed on a NFC device. However, the SSAP and DSAP can be used as identifiers for NFC link connections with the IPv6 over NFC adaptation layer. Therefore, the SSAP can be used to generate an IPv6 interface identifier. Address values between 00h and 0Fh of SSAP and DSAP are reserved for identifying the well-known service access points, which are defined in the NFC Forum Assigned Numbers Register. Address values between 10h and 1Fh are assigned by the local LLC to services registered by local service environment. In addition, address values between 0x2 and 0x3f are assigned by the local LLC as a result of an upper layer service request. Therefore, the address values between 0x2 and 0x3f can be used for generating IPv6 interface identifiers.

3.4. MTU of NFC Link Layer

As mentioned in [Section 3.2](#), when an IPv6 packet is transmitted, the packet MUST be passed down to LLC of NFC and transported to an I PDU of LLC of the NFC-enabled peer device.

The information field of an I PDU contains a single service data unit. The maximum number of octets in the information field is determined by the Maximum Information Unit (MIU) for the data link connection. The default value of the MIU for I PDUs is 128 octets. The local and remote LLCs each establish and maintain distinct MIU values for each data link connection endpoint. Also, an LLC may announce a larger MIU for a data link connection by transmitting an optional Maximum Information Unit Extension (MIUX) parameter within the information field. If no MIUX parameter is transmitted, the MIU value is 128 bytes. Otherwise, the MTU size in NFC LLC MUST be calculated from the MIU value as follows:

$$\text{MTU} = \text{MIU} = 128 + \text{MIUX}.$$

According to [[LLCP-1.4](#)], [Figure 2](#) shows an example of the MIUX parameter TLV. The Type and Length fields of the MIUX parameter TLV have each a size of 1 byte. The size of the TLV Value field is 2 bytes.

0	0	1	2	3				
0	8	6	1	1				
+-----+-----+-----+-----+								
	Type		Length		Value			
+-----+-----+-----+-----+								
	0x02		0x02		0x00		0x480	
+-----+-----+-----+-----+								

Figure 2: Example of MIUX Parameter TLV

When the MIUX parameter is used, the TLV Type field is 0x02 and the TLV Length field is 0x02. The MIUX parameter is encoded into the least significant 11 bits of the TLV Value field. The unused bits in the TLV Value field is set to zero by the sender and ignored by the receiver. The maximum possible value of the TLV Value field is 0x7FF, and the maximum size of the LLC MTU is 2175 bytes. As per the present specification [[LLCP-1.4](#)], the MIUX value MUST be 0x480 to support the IPv6 MTU requirement (of 1280 bytes) [[RFC8200](#)].

4. Specification of IPv6 over NFC

NFC technology has requirements owing to low power consumption and allowed protocol overhead. 6LoWPAN standards [[RFC4944](#)], [[RFC6775](#)], and [[RFC6282](#)] provide useful functionality for reducing the overhead

of IPv6 over NFC. This functionality consists of link-local IPv6 addresses and stateless IPv6 address auto-configuration (see [Section 4.2](#) and [Section 4.3](#)), Neighbor Discovery (see [Section 4.4](#)) and header compression (see [Section 4.6](#)).

4.1. Protocol Stack

[Figure 3](#) illustrates the IPv6 over NFC protocol stack. Upper layer protocols can be transport layer protocols (e.g., TCP and UDP), application layer protocols, and others capable of running on top of IPv6.

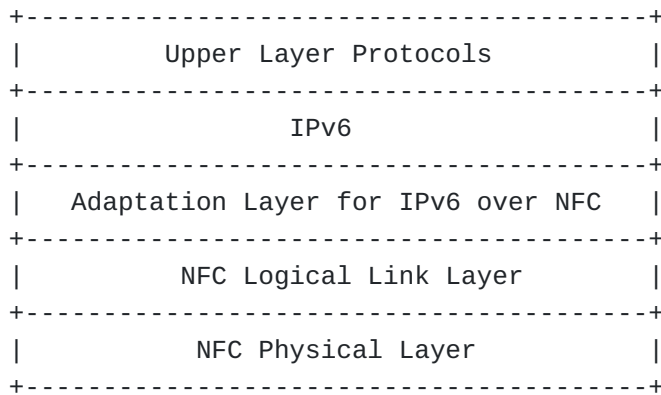


Figure 3: Protocol Stack for IPv6 over NFC

The adaptation layer for IPv6 over NFC supports neighbor discovery, stateless address auto-configuration, header compression, and fragmentation & reassembly, based on 6LoWPAN. Note that 6LoWPAN Header compression [[RFC6282](#)] does not define header compression for TCP. The latter can still be supported over IPv6 over NFC, albeit without the performance optimization of header compression.

4.2. Stateless Address Autoconfiguration

An NFC-enabled device performs stateless address autoconfiguration as per [[RFC4862](#)]. A 64-bit Interface identifier (IID) for an NFC interface is formed by utilizing the 6-bit NFC SSAP (see [Section 3.3](#)). In the viewpoint of address configuration, such an IID should guarantee a stable IPv6 address during the course of a single connection, because each data link connection is uniquely identified by the pair of DSAP and SSAP included in the header of each LLC PDU in NFC.

Following the guidance of [[RFC7136](#)], interface identifiers of all unicast addresses for NFC-enabled devices are 64 bits long and constructed by using the generation algorithm of random (but stable) identifier (RID) [[RFC7217](#)].

The RID is an output which is created by the F() algorithm with input parameters. One of the parameters is Net_Iface, and NFC Link Layer address (i.e., SSAP) MUST be a source of the Net_Iface parameter. The 6-bit address of SSAP of NFC is short and easy to be targeted by attacks of third party (e.g., address scanning). The F() algorithm with SHA-256 can provide secured and stable IIDs for NFC-enabled devices. In addition, an optional parameter, Network_ID is used to increase the randomness of the generated IID with NFC link layer address (i.e., SSAP). The secret key SHOULD be of at least 128 bits. It MUST be initialized to a pseudo-random number [RFC4086].

4.3. IPv6 Link-Local Address

The IPv6 link-local address for an NFC-enabled device is formed by appending the IID to the prefix fe80::/64, as depicted in Figure 4.

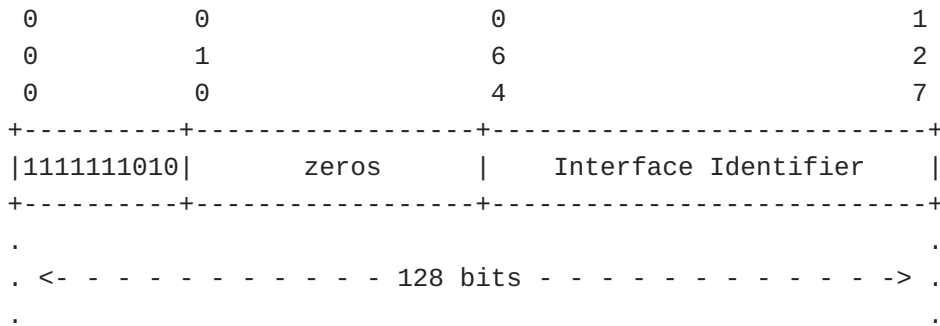


Figure 4: IPv6 link-local address in NFC

The "Interface Identifier" can be a random and stable IID.

4.4. Neighbor Discovery

Neighbor Discovery Optimization for 6LoWPANs ([RFC6775]) describes the neighbor discovery approach in several 6LoWPAN topologies, such as mesh topology. NFC supports mesh topologies, but most of all applications would use a simple multi-hop network topology or directly connected peer-to-peer network because NFC RF range is very short.

*When an NFC 6LoWPAN Node (6LN) is directly connected to an 6LBR, the 6LN MUST register its address with the 6LBR by sending Neighbor Solicitation (NS) with the Extended Address Registration Option (EARO) [RFC8505], and Neighbor Advertisement (NA) is started. When the 6LN and 6LBR are linked each other, an address is assigned to the 6LN. In this process, Duplicate Address Detection (DAD) is not required.

*When two or more NFC LNs are connected to the 6LBR, two cases of topologies can be formed. One is a multi-hop topology, and the

other is a star topology based on the 6LBR. In multi-hop topology, LNs which have two or more links with neighbor nodes may act as routers. In star topology, any of LNs can be a router.

*For receiving Router Solicitations and sending Router Advertisements, the NFC 6LNs MUST follow Sections 5.3 and 5.4 of [\[RFC6775\]](#).

*When a NFC device is a 6LoWPAN Router (6LR) or a 6LBR, the NFC device MUST follow Section 6 and 7 of [\[RFC6775\]](#).

4.5. Dispatch Header

All IPv6-over-NFC encapsulated datagrams are prefixed by an encapsulation header stack consisting of a Dispatch value [\[IANA-6LoWPAN\]](#). The only sequence currently defined for IPv6-over-NFC MUST be the LOWPAN_IPHC compressed IPv6 header (see [Section 4.6](#)) header followed by payload, as depicted in [Figure 5](#) and [Figure 6](#).

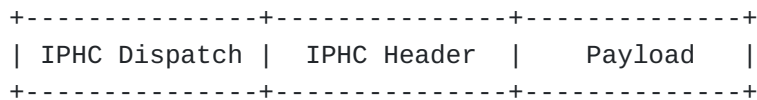


Figure 5: A IPv6-over-NFC Encapsulated LOWPAN_IPHC Compressed IPv6 Datagram

The dispatch value (length: 1 octet) is treated as an unstructured namespace. Only a single pattern is used to represent current IPv6-over-NFC functionality.

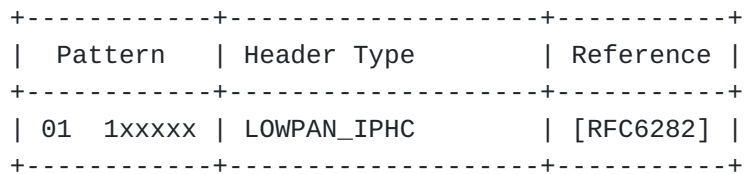


Figure 6: Dispatch Values

Other IANA-assigned 6LoWPAN Dispatch values do not apply to this specification.

4.6. Header Compression

Header compression as defined in [\[RFC6282\]](#), which specifies the compression format for IPv6 datagrams on top of IEEE 802.15.4, is REQUIRED in this document as the basis for IPv6 header compression on top of NFC. All headers MUST be compressed according to RFC 6282 encoding formats.

Therefore, IPv6 header compression in [RFC6282] MUST be implemented. Further, implementations MUST also support Generic Header Compression (GHC) of [RFC7400].

If a 16-bit address is required as a short address, it MUST be formed by padding the 6-bit NFC SSAP (NFC link-layer node address) to the left with zeros as shown in Figure 7.

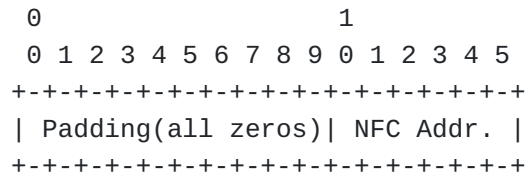


Figure 7: NFC short address format

4.7. Fragmentation and Reassembly Considerations

IPv6-over-NFC MUST NOT use fragmentation and reassembly (FAR) at the adaptation layer for the payloads as discussed in Section 3.4. The NFC link connection for IPv6 over NFC MUST be configured with an equivalent MIU size to support the IPv6 MTU requirement (of 1280 bytes). To this end, the MIUX value is 0x480.

4.8. Unicast and Multicast Address Mapping

The address resolution procedure for mapping IPv6 non-multicast addresses into NFC link-layer addresses follows the general description in Section 4.6.1 and 7.2 of [RFC4861], unless otherwise specified.

The Source/Target link-layer Address option has the following form when the addresses are 6-bit NFC SSAP/DSAP (NFC link-layer node addresses).

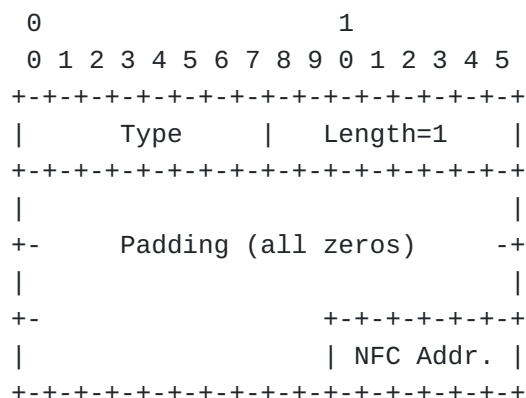


Figure 8: Unicast address mapping

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 bits. The value of this field is 1 for 6-bit NFC node addresses.

NFC address:

-The 6-bit address in canonical bit order. This is the unicast address the interface currently responds to.

The NFC Link Layer does not support multicast. Therefore, packets are always transmitted by unicast between two NFC-enabled devices. Even in the case where a 6LBR is attached to multiple 6LNs, the 6LBR cannot do a multicast to all the connected 6LNs. If the 6LBR needs to send a multicast packet to all its 6LNs, it has to replicate the packet and unicast it on each link. However, this is not energy-efficient, and the central node, which is battery-powered, must take particular care of power consumption. To further conserve power, the 6LBR MUST keep track of multicast listeners at NFC link-level granularity (not at subnet granularity), and it MUST NOT forward multicast packets to 6LNs that have not registered as listeners for multicast groups the packets belong to. In the opposite direction, a 6LN always has to send packets to or through the 6LBR. Hence, when a 6LN needs to transmit an IPv6 multicast packet, the 6LN will unicast the corresponding NFC packet to the 6LBR.

5. Internet Connectivity Scenarios

5.1. NFC-enabled Device Network Connected to the Internet

[Figure 9](#) illustrates an example of an NFC-enabled device network connected to the Internet. The distance between 6LN and 6LBR is typically 10 cm or less. For example, a laptop computer that is connected to the Internet (e.g. via Wi-Fi, Ethernet, etc.) may also support NFC and act as a 6LBR. Another NFC-enabled device may run as a 6LN and communicate with the 6LBR, as long as both are within each other's range.

Per the NFC Logical Link Control Protocol [LLCP-1.4]:

*LLCP of NFC provides protection of user data to ensure confidentiality of communications. The confidentiality mechanism involves the encryption of user service data with a secret key that has been established during link activation.

*LLCP of NFC has two modes (i.e., ad-hoc mode and authenticated mode) for secure data transfer. Ad-hoc secure data transfer can be established between two communication parties without any prior knowledge of the communication partner. Ad-hoc secure data transfer can be vulnerable to Man-In-The-Middle (MITM) attacks. Authenticated secure data transfer provides protection against Man-In-The-Middle (MITM) attacks. In the initial bonding step, the two communicating parties store a shared secret along with a Bonding Identifier.

*For all subsequent interactions, the communicating parties re-use the shared secret and compute only the unique encryption key for that session. Secure data transfer is based on the cryptographic algorithms defined in the NFC Authentication Protocol [NAP-1.0].

Furthermore, NFC is considered by many to offer intrinsic security properties due to its short link range. When interface identifiers (IIDs) are generated, devices and users are required to consider mitigating various threats, such as correlation of activities over time, location tracking, device-specific vulnerability exploitation, and address scanning. However, IPv6-over-NFC uses a [random \(but stable\) identifier \(RID\)](#) [RFC7217] as an IPv6 interface identifier, and NFC applications use short-lived connections, and a different address is used for each connection, where the latter is of extremely short duration.

8. Acknowledgements

We are grateful to the members of the IETF 6lo working group.

Michael Richardson, Suresh Krishnan, Pascal Thubert, Carsten Bormann, Alexandru Petrescu, James Woodyatt, Dave Thaler, Samita Chakrabarti, Gabriel Montenegro, Erik Kline and Carles Gomez Montenegro have provided valuable feedback for this document.

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Authors' Addresses

Younghwan Choi (editor)
Electronics and Telecommunications Research Institute
218 Gajeongno, Yuseung-gu
Daejeon
34129
South Korea

Phone: [+82 42 860 1429](tel:+82-42-860-1429)

Email: yhc@etri.re.kr

Yong-Geun Hong
Daejeon University
62 Daehak-ro, Dong-gu
Daejeon
34520
South Korea

Phone: [+82 42 280 4841](tel:+82-42-280-4841)

Email: yonggeun.hong@gmail.com

Joo-Sang Youn
DONG-EUI University
176 Eomgwangno Busan_jin_gu
Busan
614-714
South Korea

Phone: [+82 51 890 1993](tel:+82-51-890-1993)

Email: joosang.youn@gmail.com