Connection Handover

Technical Specification

NFC Forum™

Connection Handover 1.2

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RESTRICTIONS ON USE

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1 Introduction

The Connection Handover specification defines NFC Forum Well Known Types and the corresponding message structure that allows negotiation and activation of an alternative communication carrier. The negotiated communication carrier would then be used to perform certain activities between the two devices, such as printing to a Bluetooth printer or streaming video to a WLAN television set.

1.1 Objectives

The objective of this specification is to provide a generic mechanism to negotiate and activate an alternative communication carrier between two NFC Forum devices. The mechanism is intended to allow for applications to be built that need to use a communication system other than NFC to transmit relatively large amounts of data or use services not available via the NFC link.

It is not the objective of this specification to provide any definitions that are specific to alternative communication carriers or to define how an application would accomplish a given task once switched to an alternative carrier. Such information needs to be given in other specifications, either released in the future by the NFC Forum or disclosed by other organizations.

1.2 Purpose

The Connection Handover specification aims to enable applications to take advantage of NFC technology for initiating and executing user-defined activities between devices. This specification delivers a toolset that ensures compatibility between the actors, but requires further definitions to achieve full interoperability for specific alternative carrier technologies.

1.3 Mission Statement and Goals

Near Field Communication (NFC) technology can be used to design extremely intuitive user interfaces that involve activities between two devices. For example, a digital still picture camera might directly print an image that is currently shown in review mode when the user touches the camera's NFC interface to an NFC-equipped printer. Likewise, music files could be automatically synchronized between a mobile player and a home media center with a simple touch.

However, NFC alone might not be suitable for some scenarios, such as transferring large files, due to the inconvenience of keeping the interfaces of the two devices in close proximity for an extended period of time. Furthermore, many existing applications are designed to use other communication carriers and cannot be easily modified to use NFC.

The Connection Handover specification intends to solve these issues by providing the means for two NFC-equipped devices to negotiate and use an alternative communication carrier that is better suited to perform the desired task.

1.4 References

[LLCP] "NFC Logical Link Control Protocol (LLCP) Technical Specification", NFC Forum, 2009

[NDEF] "NFC Data Exchange Format (NDEF) Technical Specification", NFC Forum, 2006.

[NFC RTD] "NFC Record Type Definition (RTD) Technical Specification", NFC Forum, 2006.

[RFC 2046] N. Freed, N. Borenstein, "Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types" RFC 2046, Innosoft, First Virtual, November 1996.

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

[RFC 3986] T. Berners-Lee, R. Fielding, L. Masinter, "Uniform Resource Identifiers (URI): Generic Syntax", RFC 3986, MIT/LCS, U.C. Irvine, Xerox Corporation, January 2005.

[RFC 4234] D. Crocker, P. Overell, "Augmented BNF for Syntax Specifications: ABNF", RFC 5234, January 2008.

1.5 Administration

The NFC Forum Connection Handover specification is an open specification supported by the Near Field Communication Forum, Inc., located at:

401 Edgewater Place, Suite 600
Wakefield, MA, 01880

Tel.: +1 781-876-8955
Fax: +1 781-610-9864

http://www.nfc-forum.org/

The Reference Applications Framework Technical Working Group maintains this specification.

1.6 Special Word Usage

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 RFC 2119.

1.7 Name and Logo Usage

The Near Field Communication Forum's policy regarding the use of the trademarks *NFC Forum* and the NFC Forum logo is as follows:

- Any company MAY claim compatibility with NFC Forum specifications, whether a member of the NFC Forum or not.
- Permission to use the NFC Forum logos is automatically granted to designated members only as stipulated on the most recent Membership Privileges document, during the period of time for which their membership dues are paid.
- Member's distributors and sales representatives MAY use the NFC Forum logo in promoting member's products sold under the name of the member.
- The logo SHALL be printed in black or in color as illustrated on the Logo Page that is available from the NFC Forum at the address above. The aspect ratio of the logo SHALL be maintained, but the size MAY be varied. Nothing MAY be added to or deleted from the logos.
- Since the NFC Forum name is a trademark of the Near Field Communication Forum, the following statement SHALL be included in all published literature and advertising material in which the name or logo appears:

  NFC Forum and the NFC Forum logo are trademarks of the Near Field Communication Forum.

1.8 Intellectual Property

The Connection Handover specification conforms to the Intellectual Property guidelines specified in the NFC Forum's Intellectual Property Rights Policy, as approved on November 9, 2004 and outlined in the NFC Forum Rules of Procedures, as approved on December 17, 2004, and revised on June 23, 2007 and August 4, 2009.

1.9 Glossary

Alternative Carrier

A (wireless) communication technology that can be used for data transfers between a Handover Requester and a Handover Selector.

Carrier Configuration Data

The information needed to connect to an alternative carrier. The exact amount of information depends on the carrier technology.

Handover Requester

An NFC Forum Device that begins the Handover Protocol by issuing a Handover Request Message to another NFC Forum Device.

Handover Selector

An NFC Forum Device that constructs and replies to a Handover Select Message as a result of a previously received Handover Request Message or an NFC Forum Tag that provides a pre-set Handover Select Message for reading.

Negotiated Handover

An exchange of NDEF messages that allows two NFC Forum Devices to agree on a (set of) alternative carrier(s) to be used for further data exchange.

Static Handover

Provision of an NDEF message on an NFC Forum Tag that allows a reading NFC Forum Device to select and use alternative carriers for further data exchange.

2 Handover Protocol

2.1 Introduction

This specification defines NDEF messages that enable a Handover Requester to negotiate an alternative communication carrier with a Handover Selector over the NFC link. As a special case, it also enables a Handover Requester to retrieve the possible alternative communication carrier(s) from an NFC Forum Tag, but this has some limitations due to the static nature of information stored on a Tag. The first case is called “Negotiated Handover” and is described in section 2.2, while the second case is called “Static Handover” and is described in section 2.3.

The Handover Requester, in the scope of this specification, is defined to be the device that initiates the handover operation. The Handover Selector device is defined to be the device that is initially passive and that responds to the Handover Requester. The Handover Selector does not start any activity such as generating a handover message.

2.2 Negotiated Handover

Negotiated Handover allows two devices to negotiate one or more alternative carriers for further data exchange. The exemplary use case shown in Figure 1 illustrates how a Handover Requester uses the embedded NFC Forum Device to exchange connection handover information with the Handover Selector to finally select a matching alternative carrier. In the example, the application running on the Handover Requester first announces its alternative carriers (Wi-Fi and Bluetooth wireless technology) to the Handover Selector, and then receives a carrier selection (Bluetooth wireless technology) as the only choice, and finally performs Bluetooth pairing and data exchange.

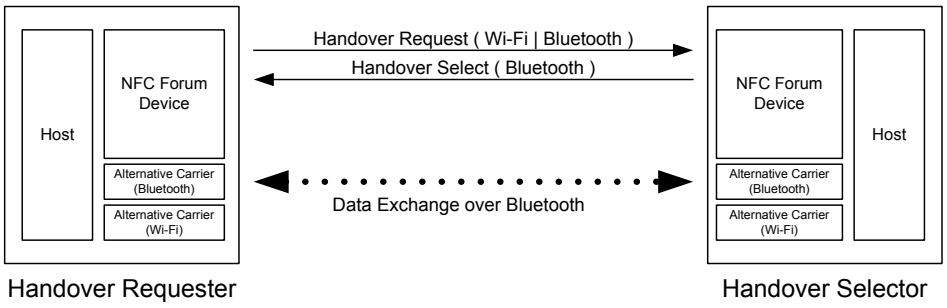

Figure 1: Negotiated Handover with Single Selection

If the Handover Selector supports multiple alternative carriers, it might return more than one selection (see Figure 2). In this case, the Handover Requester is free to choose any of the returned carriers or even try to simultaneously connect to more than one alternative carrier. However, if the Handover Requester attempts to choose one of the selected carriers, it should interpret the order that they are listed in the Handover Select message as a preference indication. In the example of Figure 2, the Handover Requester has decided against the Handover Selector’s preference for Wi-Fi and has used Bluetooth wireless technology instead.

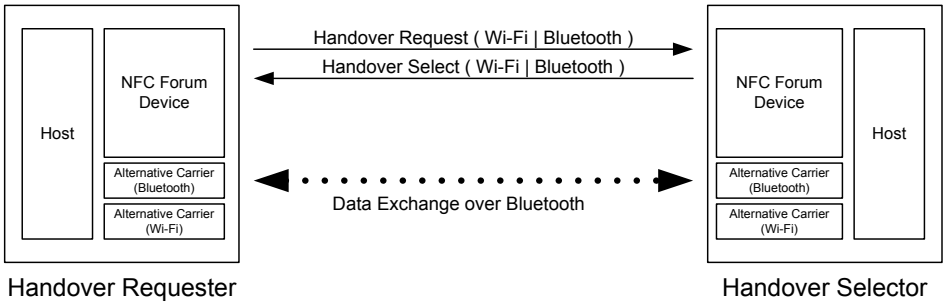

Figure 2: Negotiated Handover with Multiple Selections

A third example (Figure 3) illustrates how a Handover Requester might use a second alternative carrier selection to enhance the user experience. In the example, the Handover Selector again returns both Wi-Fi and Bluetooth wireless technology, but this time with Bluetooth wireless technology as the first preference. The Requester first tries to establish a Bluetooth connection that fails (for example, because the devices have moved outside of Bluetooth radio range). In this case, the application might decide to try the Wi-Fi connection before aborting.

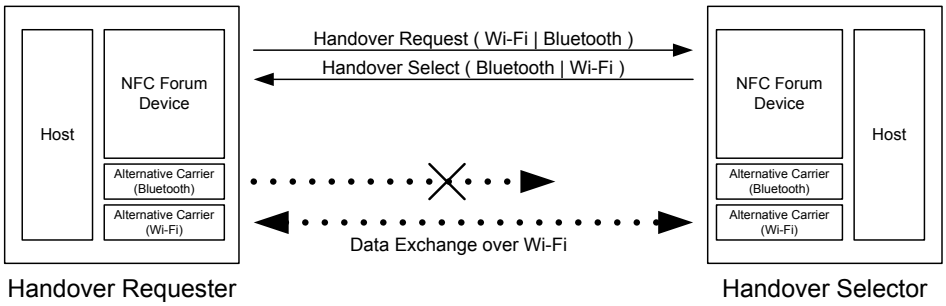

Figure 3: Negotiated Handover with Multiple Selections

A Handover Selector device with limited power resources (for example, battery driven) might not want to activate all alternative carrier circuits in case it has more than a single carrier in common with the Handover Requester. In this situation, the Handover Selector MAY set the Carrier Power State flag of all returned Alternative Carrier Records to zero (inactive). This causes the Handover Requester to send a subsequent Handover Request Message with only one of the previously received alternative carriers listed. The Handover Selector SHALL acknowledge this request with the return of a Handover Select Message (see Figure 4), where the Carrier Power State flag MUST be set to 1 (active). Note that the Handover Selector does not need to maintain state information between its two responses.

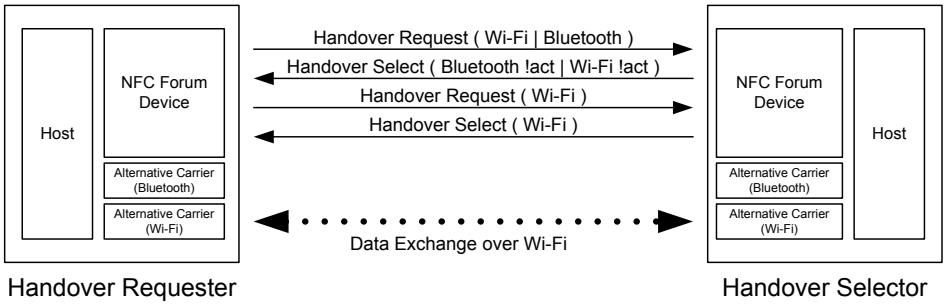

Figure 4: Negotiated Handover with a Power-constrained Device

As shown with the preceding examples, the process of a negotiated handover is performed with the exchange of two messages in the following sequence (see Figure 5):

1. The Handover Requester sends a Handover Request Message to the Handover Selector device. This message proposes a number of alternative communication carriers that the Handover Requester would be able to use for the intended activity. A proposed carrier might be provided with or without carrier configuration information. The message might state further carrier-associated requirements.
2. The Handover Selector device compares this list with its own communication facilities, possibly taking connectivity status and carrier specific requirements into account. It then returns a Handover Select Message containing a list of appropriate communication carriers, each associated with a carrier-specific configuration record. If it is not possible to use any of the proposed carriers, the Handover Selector returns an empty list.

If the Handover Selector device returns a non-empty list of alternative carriers, the handover protocol is successfully completed and establishing communication depends on the selected carrier(s). Information indicating how to establish a connection to the alternative carrier(s) MUST be provided in a carrier-specific configuration record inside the Handover Select Message and this record MUST be referenced as described in section 2.4. If the Handover Selector accepts a carrier that has been proposed with configuration information, it needs to copy the relevant information to the corresponding Handover Select Message.

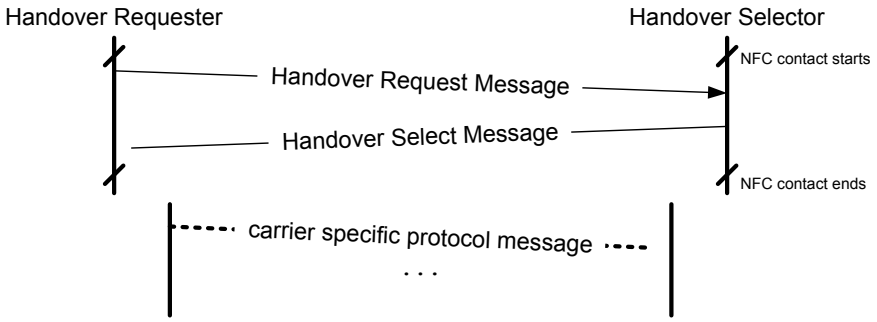

Figure 5: Negotiated Handover Message Sequence

If the Handover Selector device does not acknowledge at least one of the proposed alternative carriers, the Handover Requester might want to repeat the sequence with different settings. This

could be useful if the Handover Requester has a strong preference on a certain communication carrier or properties. However, the Handover Selector device SHOULD compare the proposed carriers in the same order as they are listed in the Handover Request Message and give preference to those listed first.

A Handover Selector SHOULD answer a Handover Request Message within 1 second; otherwise, the Handover Requester MAY assume a processing error. Note that the message transport layer is assumed to guarantee delivery of Handover messages over the NFC link. See section 2.8 for more details.

2.3 Static Handover

The Static Handover can be used when the Handover Selector device does not constitute an NFC Forum Device but has a (cheaper) NFC Forum Tag attached (see Figure 6). NFC Forum Tags provide storage space that can be read or written but might not have an internal connection with the Host processor. It is not possible for an NFC Forum Tag to receive and interpret a Handover Request Message and to dynamically construct a corresponding Handover Select Message.

In this case, the Tag contains a Handover Select Record plus additional information records that are referenced as described in section 2.4. Because this is static information, it cannot be adapted to any possible requirements that a Handover Requester might provide with Negotiated Handover. Also, dynamic information (for example, a dynamically-assigned IP address) cannot be provided sensibly.

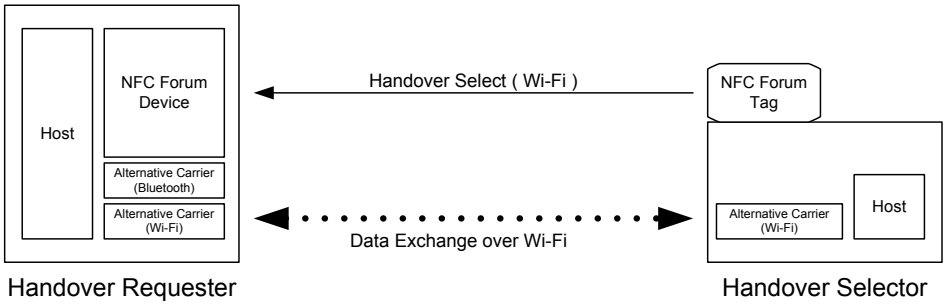

Figure 6: Static Handover

A further drawback of Static Handover is that the Handover Selector's Host processor will not be able to activate its alternative carrier circuits as part of the handover process. All carrier circuits either have to be continuously active or have to be activated explicitly by the user.

2.4 Message Composition

A handover message is composed of either a Handover Request Record (NFC Forum Global Type "Hr") or a Handover Select Record (NFC Forum Global Type "Hs"), followed by an arbitrary number of other NDEF records.

Within a Handover Request or Handover Select Record, a sequence of Alternative Carrier Records (NFC Forum Local Type "ac") defines the alternative carriers that are requested or selected, respectively. The actual information is provided with the NDEF records that follow the leading message record, and the Alternative Carrier Record provides references to those belonging to the given alternative carrier (see Figure 7).

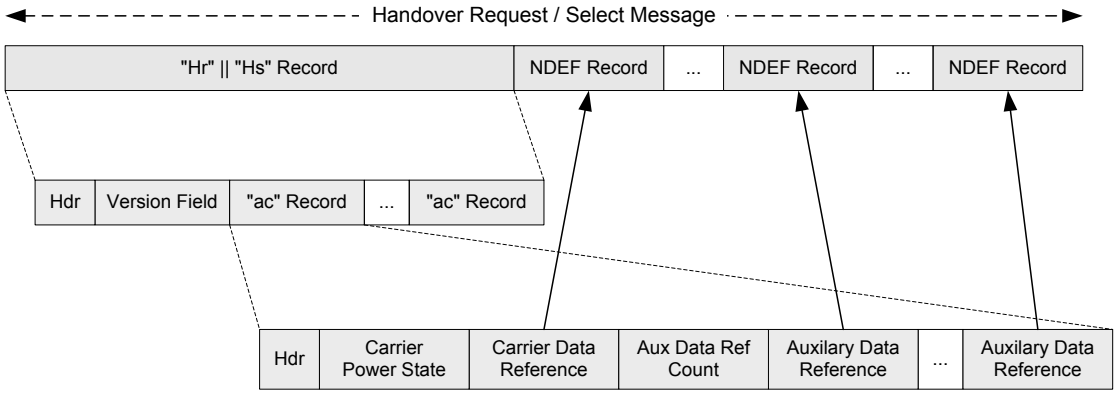

Figure 7: General Message Composition

The record references are established using the URI-based Payload Identification mechanism described in the NDEF specification [NDEF]. The URI reference values SHALL be encoded as relative URIs with the virtual base defined as “urn:nfc:handover:”.

The message generator is responsible for the uniqueness of the payload identifiers encoded into the ID field of the NDEF record header. While identifiers can be strings of length up to 255 characters, it is RECOMMENDED that short, possibly single character, strings are used. However, the generator SHALL NOT use the tilde character (“~”, hexadecimal 7E) at the first string position and a compliant parser SHALL ignore strings starting with a tilde character.

2.5 Carrier Type Identification

The type of carrier described by an Alternative Carrier Record is indirectly given via the Carrier Data Reference link.

If the referenced NDEF record is a Handover Carrier Record (NFC Forum Global Type “Hc”) as defined in this specification, the carrier type is identified by the Carrier Name structure within the payload of the Handover Carrier Record. The syntax of the Carrier Name structure is equivalent to the NDEF record type. The Handover Carrier Record MUST be used by a Handover Requester when an alternative carrier is proposed without configuration data.

If the referenced NDEF record is not a Handover Carrier Record, then the carrier type is identified with the NDEF record payload type (the triple {*TNF*, *TYPE_LENGTH*, *TYPE*}), and the payload of the record MUST provide carrier-specific configuration information as needed to connect to the carrier. For brevity, this type of NDEF record is called Carrier Configuration Record, but this is only a conceptual name, and no record named such is defined in this specification.

2.6 Carrier Power State

Handover devices with limited power resources might want to activate (that is, power up) carrier circuits only when they are requested to by a handover activity. For this purpose, a device can indicate the power status for each of the proposed or available alternative carriers within the Alternative Carrier Record. The possible values for the Carrier Power State are defined in Table 2. For brevity, we will refer to them as “active”, “inactive”, “activating”, or “unknown”.

If a carrier is declared “active” and carrier configuration data is provided, the peer device MAY immediately use the configuration data and connect to the carrier.

If the carrier power state is “activating”, the peer device SHOULD expect a delay when trying to connect to the carrier because the circuit was not yet powered when the message was sent out. The exact time needed to activate the carrier is dependent on both technology and implementation and cannot be defined here. It MAY be defined by other organizations.

If a Handover Requester proposes carriers with power state “activating”, it MAY wait for the Handover Selector’s Handover Select Message before actually powering the circuit.

If a Handover Selector does acknowledge carriers with power state “activating”, it SHALL immediately start the activation process after returning the Handover Select Message.

A Handover Selector MAY return one or multiple alternative carriers (with carrier configuration data) that are declared “inactive” if the Handover Requester provided more than one alternative in the Handover Request Message. The Handover Requester SHOULD then request exactly one alternative carrier in a subsequent Handover Request Message. The Handover Selector SHALL respond to this request with the alternative carrier that is declared either “active” or “activating”.

If the Handover Selector is an NFC Forum Tag (Static Handover), it MAY provide a number of “inactive” alternative carriers inside a Handover Select Message stored on the tag. This usually means that the user is expected to manually activate carrier circuits on the device. Nevertheless, a Handover Requester could first try to connect to the carrier(s) because they might have been already activated.

The carrier power state “unknown” is used when the device does not directly support an interface for that carrier and can only be reached via the alternative carrier through a router. However, note that the device MUST be able to provide sufficient carrier configuration data for the peer device to connect to the alternative carrier.

The power state “unknown” MAY be used in both Handover Request and Handover Select messages.

If on-demand activation is used, the implementation should keep the carrier(s) active for a time interval long enough to allow the peer device to connect to the carrier. The value depends on the carrier technology.

2.7 Handover Request Collision

A handover request collision happens if both devices simultaneously send a Handover Request Message after the NFC communication link has been established by the underlying peer-to-peer protocol. Note that if a device intends to send a Handover Request message but receives a Handover Request message from the other device before sending, it SHALL NOT send a Handover Request message but instead take the role of a “Handover Selector device”.

If a device detects that a Handover Request collision has occurred (that is, it has sent a Handover Request Message and then received a Handover Request Message), it SHALL compare the random number within the received Handover Request Message against the random number transmitted with the sent Handover Request Message. The random number is contained within a Collision Resolution Record in each Handover Request Message.

The random number comparison shall be performed on both devices with the following steps:

1. Numerically compare the received random number with the sent random number to determine equality or the greater value of both.

2. If both random numbers are numerically equal. then automatic collision resolution will not be possible and the device SHOULD generate and send a new Handover Request Message.
3. If the two random numbers are not equal, then compare the least significant bit of the received random number with the least significant bit of the sent random number.
   - If the two bits have the same value, then the device that sent the numerically greater random number SHALL assume the role of a "Handover Selector device", and the device that sent the numerically lower random number SHALL silently ignore the received Handover Request Message.
   - If the two bits have a different value, then the device that sent the numerically lower random number SHALL assume the role of a "Handover Selector device", and the device that sent the numerically greater random number SHALL silently ignore the received Handover Request Message.

2.8 Message Transport

In the NFC Forum protocol stack, handover messages SHALL be exchanged over an LLCP data link connection between a handover requester and a handover selector application. A handover requester application SHALL send handover request messages and accept handover select messages as response. A handover selector application SHALL accept handover request messages and send handover select messages in response.

A single handover request or handover response message SHALL be transmitted as a contiguous sequence of octets within the information field(s) of consecutively numbered I PDUs defined by [LLCP]. The number of octets in the information field of the last I PDU transmitting a specific handover message SHALL be equal to the number of data octets that have not been transmitted with the preceding I PDUs. The receiver of a handover message SHALL determine the total length of transmitted data by observing the message begin, message end, and record length NDEF header fields of the top-level records comprising the NDEF message.

If a handover selector application is available on the local device, it SHALL be registered with the local service discovery component by the service name "urn:nfc:sn:handover", such that a remote handover requester application is able to use the SDP protocol to learn the assigned service access point address for the handover service or issue a CONNECT PDU with the service name parameter set to "urn:nfc:sn:handover".

A handover selector application registered by the service name "urn:nfc:sn:handover" SHALL silently discard connection-less transport mode PDUs.

2.9 Version Handling

Both Handover Request Message and Handover Select Message carry a version number field that SHALL be set equal to the version number of the Connection Handover specification, after which the message content is encoded. The version number is divided into a major and a minor part. A change in the minor version number part indicates backward-compatible changes in the specification that do not affect interoperability. A change in the major version number part implies significant modifications in syntax or semantics, and parsers supporting only prior versions SHALL NOT further interpret the data.

If version numbers do not match exactly, the following rules apply:

- If a Handover Selector reads a Handover Request message with a version number that differs only in the minor part, it SHALL reply with a Handover Select Message formatted according to its own version number.
- If a Handover Selector reads a Handover Request Message with a version number that differs in the major part and is higher than its own version number, it SHALL reply with an empty Handover Select Message (one that does not contain any Alternative Carrier records), and the version number field SHALL be set to the highest supported value.
- If a Handover Selector reads a Handover Request message with a version number that differs in the major part and is lower than its own version number, it MAY reply with an empty Handover Select Message indicating only the version number conflict, or it MAY reply with a Handover Select Message formatted according to the major version used by the Handover Requester.

2.10 Security Considerations

This section is meant to inform application developers and users of the security limitations in the Negotiated and Static Handover protocol described in this specification.

The Handover Protocol requires transmission of network access data and credentials (the carrier configuration data) to allow one device to connect to a wireless network provided by another device. Because of the close proximity needed for communication between NFC Devices and Tags, eavesdropping of carrier configuration data is difficult, but not impossible, without recognition by the legitimate owner of the devices. Transmission of carrier configuration data to devices that can be brought to close proximity is deemed legitimate within the scope of this specification.

In case the legitimate owner of the devices has concerns over the confidentiality of the data, an additional security analysis is necessary that takes the system in question and the operating environment into account.

3 NDEF Structure

The ABNF definition of the Handover messages and records is given in normative Appendix A.

3.1 Message Definitions

3.1.1 Handover Request Message

The Handover Request message is used by a Handover Requester device to propose a number of alternative carriers to the Handover Selector device. The message MUST start with a Handover Request Record that has the message begin (MB) flag set and MUST be followed by a number of NDEF records. The last NDEF record closes the message with the message end (ME) flag set.

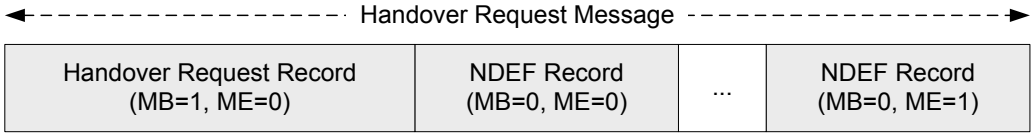

Figure 8: Handover Request Message Structure

Note that a sole Handover Request record with MB and ME set to 1 would not be valid because a Handover Request Message transmits at least one Handover Carrier or Carrier Configuration record to indicate a single alternative carrier.

3.1.2 Handover Select Message

The Handover Select Message is used by the Handover Selector device to acknowledge alternative carriers that were listed in the previously received Handover Request Message. The message MUST start with a Handover Select Record that has the message begin (MB) flag set and MAY be followed by a number of NDEF records, the last one closing the message with the message end (ME) flag set. In case no additional records are transmitted, the Handover Select Record SHALL have both the MB and ME flag set to one.

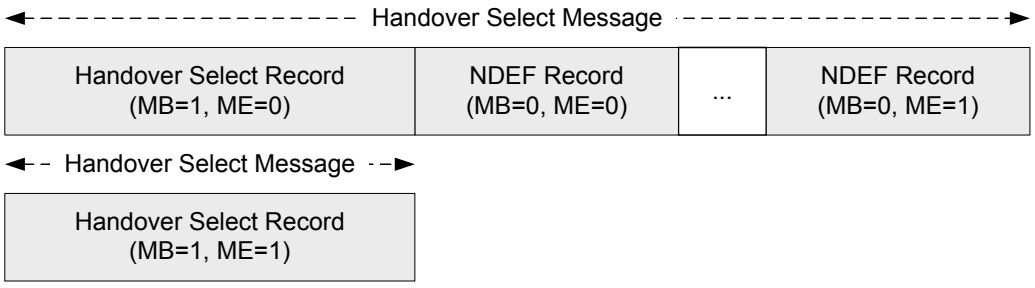

Figure 9: Handover Select Message Structure

Note that a sole Handover Select Record with both MB and ME set to 1 is a valid Handover Select Message that is transmitted if either no matching alternative carrier could be identified or if the version number in the Handover Request Message indicates a message format not supported by the Handover Selector.

3.2 Global Record Definitions

3.2.1 Handover Request Record

The Handover Request Record identifies a list of possible alternative carriers that the Handover Requester device would be able to use for further communication with the Handover Selector. At least a single alternative carrier MUST be specified by the Handover Requester. If multiple alternative carriers are specified, the Handover Selector SHOULD process the records in order and acknowledge the first appropriate match, if any.

Only Alternative Carrier Records or Collision Resolution Records have a defined meaning in the payload of a Handover Request Record. However, an implementation SHALL silently ignore and SHALL NOT raise an error if it encounters other unknown record types.

The NFC Forum Well Known Type [NDEF], [NFC RTD] for the Handover Request Record is "Hr" (in NFC binary encoding: 0x48, 0x72).

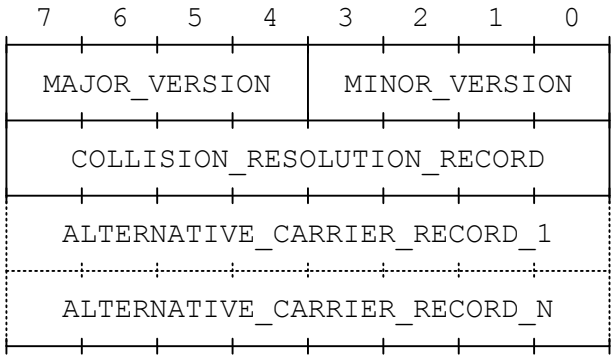

Figure 10: Payload of the Handover Request Record

Semantics for the Handover Request Record:

MAJOR_VERSION: This 4-bit field equals the major version number of the Connection Handover specification and SHALL be set to 0x1 by an implementation that conforms to this specification. When an NDEF parser reads a different value, it SHALL NOT assume backward compatibility.

MINOR_VERSION: This 4-bit field equals the minor version number of the Connection Handover specification and SHALL be set to 0x2 by an implementation that conforms to this specification. When an NDEF parser reads a different value, it MAY assume backward compatibility.

COLLISION_RESOLUTION_RECORD: This record contains a 16-bit random number that is used in the collision resolution procedure defined in section 2.7. Only a single Collision Resolution Record SHALL be allowed in a Handover Request Message. The Collision Resolution Record is defined in section 3.3.2.

ALTERNATIVE_CARRIER_RECORD: Each record specifies a single alternative carrier that the Handover Requester would be able to use for further communication with the Handover Selector device. The Alternative Carrier Record is defined in section 3.3.1.

3.2.2 Handover Select Record

The Handover Select Record identifies the alternative carriers that the Handover Selector device selected from the list provided within the previous Handover Request Message. The Handover Selector MAY acknowledge zero, one, or more of the proposed alternative carriers at its own discretion.

Only Alternative Carrier Records and Error Records have a defined meaning in the payload of a Handover Select Record. However, an implementation SHALL NOT raise an error if it encounters other record types, but SHOULD silently ignore them.

The NFC Forum Well Known Type [NDEF], [NFC RTD] for the Handover Select record is “Hs” (in NFC binary encoding: 0x48, 0x73).

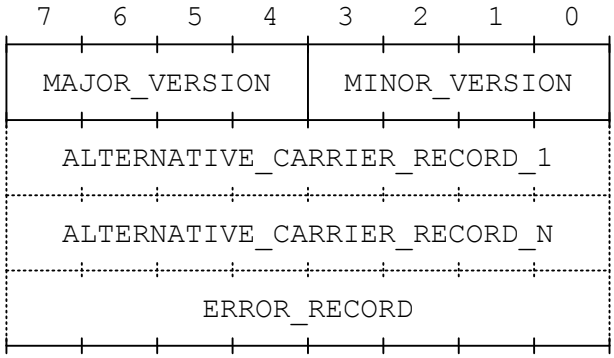

Figure 11: Payload of the Handover Select Record

Semantics for the Handover Select Record:

MAJOR_VERSION: This 4-bit field equals the major version number of the Connection Handover specification and SHALL be set to 0x1 by an implementation that conforms to this specification. When an NDEF parser reads a different value, it SHALL NOT assume backward compatibility.

MINOR_VERSION: This 4-bit field equals the minor version number of the Connection Handover specification and SHALL be set to 0x2 by an implementation that conforms to this specification. When an NDEF parser reads a different value, it MAY assume backward compatibility.

ALTERNATIVE_CARRIER_RECORD: Each record specifies a single alternative carrier that the Handover Selector would be able to use for further communication with the Handover Requester device. The order of the Alternative Carrier Records gives an implicit preference ranking that the Handover Requester SHOULD obey. The Alternative Carrier Record is defined in section 3.3.1.

ERROR_RECORD: This record indicates that the Handover Selector was not able to successfully process the Handover Request Message, either in part or entirely. Only a single Error Record SHALL be allowed in a Handover Select Message. Alternative Carrier Records encoded before an Error Record SHALL be complete and regarded as valid information. Alternative Carrier Records SHALL NOT be encoded after an Error Record. The Error Record is defined in section 3.3.3

3.2.3 Handover Carrier Record

The Handover Carrier Record provides a unique identification of an alternative carrier technology in Handover Request messages when no carrier configuration data is to be provided. If the Handover Selector has the same carrier technology available, it would respond with a Carrier Configuration record with payload type equal to the carrier type (that is, the triples {*TNF, TYPE_LENGTH, TYPE*} and {*CTF, CARRIER_TYPE_LENGTH, CARRIER_TYPE*} match exactly).

The NFC Forum Well Known Type [NDEF], [NFC RTD] for the Handover Carrier Record is "Hc" (in NFC binary encoding: 0x48, 0x63).

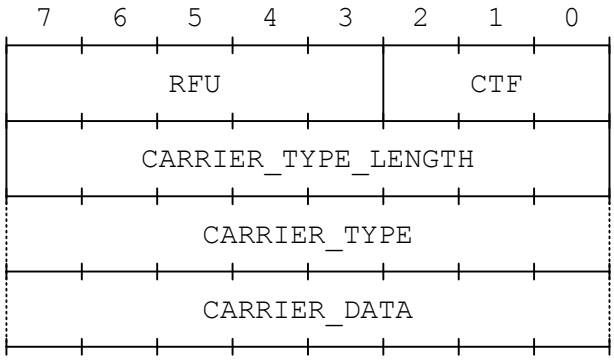

Figure 12: Handover Carrier Record Encoding

Semantics for the Handover Carrier Record:

CTF (Carrier Type Format): This is a 3-bit field that indicates the structure of the value of the *CARRIER_TYPE* field. Allowed values are listed in Table 1; other values SHALL NOT be used. The *CTF* field has the same semantics as the NDEF record *TNF* (Type Name Format) field and further explanation can be found in the NDEF specification [NDEF].

Table 1: Allowed CTF Field Values

Value	Carrier Type Format
0x01	NFC Forum well-known type [NFC RTD]
0x02	Media-type as defined in RFC 2046 [RFC 2046]
0x03	Absolute URI as defined in RFC 3986 [RFC 3986]
0x04	NFC Forum external type [NFC RTD]

CARRIER_TYPE: The value of the *CARRIER_TYPE* field gives a unique identification of the alternative carrier (see section 2.5). The value of the *CARRIER_TYPE* field MUST follow the structure, encoding, and format implied by the value of the *CTF* field.

CARRIER_DATA: A sequence of octets that provide additional information about the alternative carrier enquiry. The syntax and semantics of this data are determined by the *CARRIER_TYPE* field. The number of *CARRIER_DATA* octets is equal to the NDEF record *PAYLOAD_LENGTH* minus the *CARRIER_TYPE_LENGTH* minus 2.

3.3 Local Record Definitions

3.3.1 Alternative Carrier Record

The Alternative Carrier Record is used in the Handover Request Record or the Handover Select Record to describe a single alternative carrier. It SHALL NOT be used elsewhere.

The carrier type structure is the basic identification of an alternative carrier. The possible values are the same as those that can be assigned to the NDEF payload type field (see [NDEF]).

The list of Payload ID References is used to provide additional information by referencing other NDEF records within the Handover Request or Handover Select Message. This list can contain any number of links, including none.

The NFC Forum Well Known Local Type [NDEF], [NFC RTD] for the Alternative Carrier Record is “ac” (in NFC binary encoding: 0x61, 0x63).

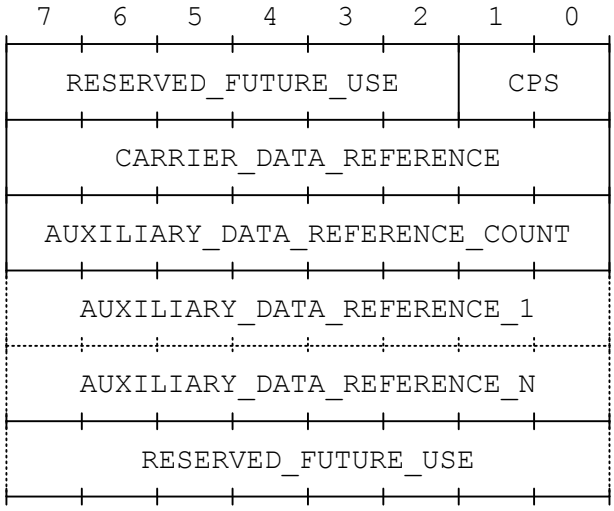

Figure 13: Alternative Carrier Record Layout

Semantics for the Alternative Carrier Record:

CPS (Carrier Power State): This is a 2-bit field that indicates the carrier power state. Possible values are described in Table 2.

Table 2: Carrier Power State Values

Value	Carrier Power State
0x00	Inactive; the carrier is currently off
0x01	Active; the carrier is currently on
0x02	Activating; the device is in the process of activating the carrier, but it is not yet active.
0x03	Unknown; the device is only reachable via the carrier through a router, and it does not directly support an interface for the carrier.

CARRIER_DATA_REFERENCE: The Carrier Data Reference is a pointer to an NDEF record that uniquely identifies the carrier technology. The pointed record MAY be either a Handover Carrier record (see section 3.2.3) or a Carrier Configuration record (see section 2.5). A Carrier Data Reference is encoded as an 8-bit length field that determines the number of the following carrier data reference characters (see Figure 14).

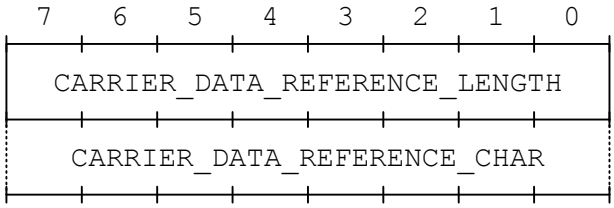

Figure 14: Carrier Data Reference Encoding

AUXILIARY_DATA_REFERENCE_COUNT: This is an 8-bit integer field that defines the number of the following Auxiliary Data References.

AUXILIARY_DATA_REFERENCE: An Auxiliary Data Reference is a pointer to an NDEF record that gives additional information about the alternative carrier. No limitations are imposed on the type of record being pointed to. An Auxiliary Data Reference is encoded as an 8-bit length field that determines the number of the following auxiliary data reference characters.

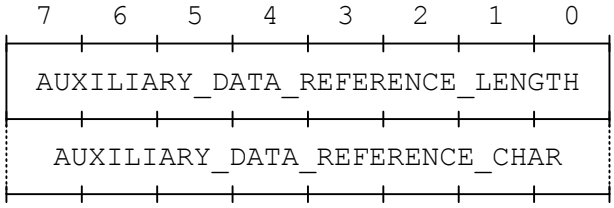

Figure 15: Auxiliary Data Reference Encoding

3.3.2 Collision Resolution Record

The Collision Resolution Record is used in the Handover Request Record to transmit the random number required to resolve a collision of handover request messages. It SHALL NOT be used elsewhere.

The NFC Forum Well Known Local Type [NDEF], [NFC RTD] for the Collision Resolution Record is “cr” (in NFC binary encoding: 0x63, 0x72).

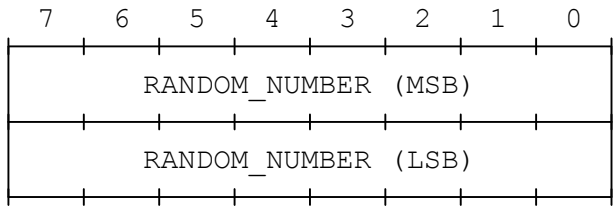

Figure 16: Payload of the Collision Resolution Record

Semantics for the Collision Resolution Record:

RANDOM_NUMBER: This 16-bit field contains an integer number that SHALL be randomly generated before sending a Handover Request Message.

3.3.3 Error Record

The Error Record is used in the Handover Select Record to indicate that the Handover Selector failed to successfully process the most recently received Handover Request Message. It SHALL NOT be used elsewhere.

The NFC Forum Well Known Local Type [NDEF], [NFC RTD] for the Error Record is "err" (in NFC binary encoding: 0x65, 0x72, 0x72).

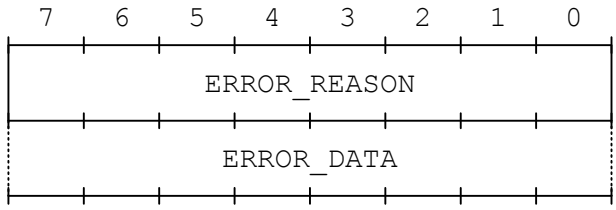

Figure 17: Payload of the Error Record

Semantics for the Error Record:

ERROR_REASON: An 8-bit field that indicates the specific type of error that caused the Handover Selector to return the Error Record. Possible values are described in Table 3.

Table 3: Error Reason Values

Value	Description
0x00	Reserved
0x01	The Handover Request Message could not be processed due to temporary memory constraints. Resending the unmodified Handover Request Message might be successful after a time interval of at least the number of milliseconds expressed in the error data field.
0x02	The Handover Request Message could not be processed due to permanent memory constraints. Resending the unmodified Handover Request Message will always yield the same error condition.

Value	Description
0x03	The Handover Request Message could not be processed due to carrier-specific constraints. Resending the Handover Request Message might not be successful until after a time interval of at least the number of milliseconds expressed in the error data field.
0x04 – 0xFF	Reserved.

ERROR_DATA: A sequence of octets providing additional information about the conditions that caused the handover selector to enter erroneous state. The syntax and semantics of this data are determined by the ERROR_REASON field and are specified in Table 4. The number of octets encoded in the ERROR_DATA field SHALL be determined by the number of octets in the payload of the Error Record minus 1.

Table 4: Contents of the Error Data Field

Error Reason Value	Content of the Error Data field
0x01	An 8-bit unsigned integer that expresses the minimum number of milliseconds after which a Handover Request Message with the same number of octets might be processed successfully. The number of milliseconds SHALL be determined by the time interval between the sending of the error indication and the subsequent receipt of a Handover Request Message by the Handover Selector.
0x02	A 32-bit unsigned integer, encoded with the most significant byte first, that indicates the maximum number of octets of an acceptable Handover Select Message. The number of octets SHALL be determined by the total length of the NDEF message, including all header information.
0x03	An 8-bit unsigned integer that expresses the minimum number of milliseconds after which a Handover Request Message might be processed successfully. The number of milliseconds SHALL be determined by the time interval between the sending of the error indication and the subsequent receipt of a Handover Request Message by the Handover Selector.

A. ABNF Definition of Handover Messages and Records

This section defines the normative requirements for the handover messages and records. The language used is the ABNF format as defined in Augmented BNF for Syntax Specifications: ABNF [RFC 5234].

```
handover_request_message          = handover_request_record 1*NDEF_record
handover_select_message           = handover_select_record *NDEF_record

handover_request_record           = NDEF_header "Hr" handover_request_payload
handover_select_record            = NDEF_header "Hs" handover_select_payload

NDEF_header                       = header_flags record_type_length payload_length
header_flags                      = OCTET
record_type_length                = OCTET
payload_length                    = OCTET / UINT32

handover_request_payload          = version_number
                                  = collision_resolution_record
                                    1*alternative_carrier_record

handover_select_payload           = version_number
                                    *alternative_carrier_record
                                    error_record

version_number                    = OCTET

collision_resolution_record       = random_number

random_number                     = UINT16

alternative_carrier_record        = carrier_state_flags
                                    carrier_data_reference
                                    auxiliary_data_reference_count
                                    *auxiliary_data_reference
                                    *reserved_bytes

carrier_state_flags               = OCTET
carrier_data_reference            = payload_reference

auxiliary_data_reference_count    = OCTET
auxiliary_data_reference          = payload_reference

payload_reference                 = payload_reference_length
                                    payload_reference_name

payload_reference_length          = payload_id_length
payload_reference_name            = payload_id

handover_carrier_record           = NDEF_header ID_length "Hc" payload_ID
                                    handover_carrier_payload

handover_carrier_payload          = carrier_type_flags carrier_type_length
                                    carrier_type [carrier_data]

carrier_type_flags                = OCTET
carrier_type_length               = OCTET
carrier_type                      = 1*OCTET
carrier_data                      = 1*OCTET

payload_id_length                 = OCTET
payload_id                        = 1(ALPHA / DIGIT / "-" / "_" / "." / ":")
                                    *(ALPHA / DIGIT / "-" / "_" / "." / ":" / "~")

error_record                      = error_reason *error_data
error_reason                      = OCTET
error_data                        = *OCTET

reserved_bytes                    = OCTET
```

Notes:

- *_length and *_count fields. All elements in the grammar with a suffix of "_length" or "_count" contain unsigned 8-bit binary integers indicating the size or number of corresponding fields in the record. For example, payload_reference_count indicates the number of payload_reference fields that follow.
- version_number. This octet consists of two 4-bit subfields. The high-order 4 bits contain the major version number. The low-order 4 bits contain the minor version number. By convention, backward compatibility is assured unless the major version number changes. For example, 0x10 corresponds to version 1.0.
- carrier_state_flags. The two low-order bits of carrier_state_flags reflect the status of the alternative carrier interface with values defined in Table 2. The high-order six bits of carrier_state_flags are reserved for future use and MUST be ignored by version 1.0 implementations.
- carrier_type_flags. The three low-order bits of carrier_type_flags define the format of the carrier_type filed with values as defined in Table 1. The high-order five bits of carrier_type_flags are reserved for future use and MUST be ignored by version 1.0 implementations.
- reserved_bytes. This is a placeholder for future backward-compatible extensions of the alternative_carrier_record. If reserved_bytes octets are present, Version 1.0 implementations MUST ignore them.
- NDEF_header (header_flags, record_type_length, payload_length). These fields are as documented in the NFC Data Exchange Format [NDEF] specification.
- UINT16. This field corresponds to a 16-bit unsigned integer in network byte order.
- UINT32. This field corresponds to a 32-bit unsigned integer in network byte order.

B. Revision History

The following table outlines the revision history of Connection Handover.

Table 5: Revision History

Document Name	Revision and Release Date	Status	Change Notice	Supersedes
Connection Handover Candidate Technical Specification	1.0, April 2008	Candidate	None	
Connection Handover Technical Specification	1.1, November 2008	Final		1.0
Connection Handover Technical Specification	1.2, July 2010	Final	Defines the transport of connection handover messages over LLCP. Defines handover request collision resolution.	1.1