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Context Transfer Protocol

Status of this Memo

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Abstract

This document presents a context transfer protocol that enables authorized context transfers. Context transfers allow better support for node based mobility so that the applications running on mobile nodes can operate with minimal disruption. Key objectives are to reduce latency, packet losses and avoiding re-initiation of signaling

to and from the mobile node.

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1. Introduction

This document describes the Context Transfer Protocol overview, which provides:

* Representation for feature contexts.
* Messages to initiate and authorize context transfer, and notify a mobile node of the status of the transfer.
* Messages for transferring contexts prior to, during and after handovers.

The proposed protocol is designed to work in conjunction with other protocols in order to provide seamless mobility. The protocol supports both IPv4 and IPv6, though support for IPv4 private addresses is for future study.

1.1 The Problem

"Problem Description: Reasons For Performing Context Transfers between Nodes in an IP Access Network" [RFC3374] defines the following main reasons why Context Transfer procedures may be useful in IP networks.

1) The primary motivation, as mentioned in the introduction, is the need to quickly re-establish context transfer-candidate services without requiring the mobile host to explicitly perform all protocol flows for those services from scratch. An example of a service is included in Appendix B.

2) An additional motivation is to provide an interoperable solution that supports various Layer 2 radio access technologies.

1.2 Conventions Used in This Document

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 [RFC2119].

1.3 Abbreviations Used in the Document

Mobility Related Terminology [TERM] defines basic mobility terminology. In addition to the material in that document, we use the following terms and abbreviation in this document.

CTP	Context Transfer Protocol
DoS	Denial-of-Service

FPT	Feature Profile Types
PCTD	Predictive Context Transfer Data

2. Protocol Overview

This section provides a protocol overview. A context transfer can be either started by a request from the mobile node ("mobile controlled") or at the initiative of either the new or the previous access router ("network controlled").

* The mobile node (MN) sends the CT Activate Request (CTAR) to its current access router (AR) immediately prior to handover whenever possible to initiate predictive context transfer. In any case, the MN always sends the CTAR message to the new AR (nAR). If the contexts are already present, nAR verifies the authorization token present in CTAR with its own computation using the parameters supplied by the previous access router (pAR), and subsequently activates those contexts. If the contexts are not present, nAR requests pAR to supply them using the Context Transfer Request message, in which it supplies the authorization token present in CTAR.

* Either nAR or pAR may request or start (respectively) context transfer based on internal or network triggers (see Appendix A).

The Context Transfer protocol typically operates between a source node and a target node. In the future, there may be multiple target nodes involved; the protocol described here would work with multiple target nodes. For simplicity, we describe the protocol assuming a single receiver or target node.

Typically, the source node is a MN's pAR and the target node is MN's nAR. Context Transfer takes place when an event, such as a handover, takes place. We call such an event a Context Transfer Trigger. In response to such a trigger, the pAR may transfer the contexts; the nAR may request contexts; and the MN may send a message to the routers to transfer contexts. Such a trigger must be capable of providing the necessary information (such as the MN's IP address) by which the contexts are identified, the IP addresses of the access routers, and authorization to transfer context.

Context transfer protocol messages use Feature Profile Types (FPTs) that identify the way that data is organized for the particular feature contexts. The FPTs are registered in a number space (with IANA Type Numbers) that allows a node to unambiguously determine the type of context and the context parameters present in the protocol messages. Contexts are transferred by laying out the appropriate

feature data within Context Data Blocks according to the format in Section 2.3, as well as any IP addresses necessary to associate the contexts to a particular MN. The context transfer initiation messages contain parameters that identify the source and target nodes, the desired list of feature contexts and IP addresses to identify the contexts. The messages that request transfer of context data also contain an appropriate token to authorize the context transfer.

Performing context transfer in advance of the MN attaching to nAR can increase handover performance. For this to take place, certain conditions must be met. For example, pAR must have sufficient time and knowledge about the impending handover. This is feasible, for instance, in Mobile IP fast handovers [LLMIP][FMIPV6]. Additionally, many cellular networks have mechanisms to detect handovers in advance. However, when the advance knowledge of impending handover is not available, or if a mechanism such as fast handover fails, retrieving feature contexts after the MN attaches to nAR is the only available means for context transfer. Performing context transfer after handover might still be better than having to re-establish all the contexts from scratch. Finally, some contexts may simply need to be transferred during handover signaling. For instance, any context that gets updated on a per-packet basis must clearly be transferred only after packet forwarding to the MN on its previous link is terminated.

2.1 Context Transfer Scenarios

The Previous Access Router transfers feature contexts under two general scenarios.

2.1.1 Scenario 1

The pAR receives a Context Transfer Activate Request (CTAR) message from the MN whose feature contexts are to be transferred, or it receives an internally generated trigger (e.g., a link-layer trigger on the interface to which the MN is connected). The CTAR message, described in Section 2.5, provides the IP address of nAR, the IP address of MN on pAR, the list of feature contexts to be transferred (by default requesting all contexts to be transferred), and a token authorizing the transfer. In response to a CT-Activate Request message or to the CT trigger, pAR predictively transmits a Context Transfer Data (CTD) message that contains feature contexts. This message, described in Section 2.5, contains the MN's previous IP address. It also contains parameters for nAR to compute an authorization token to verify the MN's token present in CTAR message. Recall that the MN always sends CTAR message to nAR regardless of whether it sent the CTAR message to pAR. The reason for this is that there is no means for the MN to ascertain that context transfer

reliably took place. By always sending the CTAR message to nAR, the Context Transfer Request (see below) can be sent to pAR if necessary.

When context transfer takes place without the nAR requesting it, nAR requires MN to present its authorization token. Doing this locally at nAR when the MN attaches to it improves performance and increases security, since the contexts are highly likely to be present already. Token verification takes place at the router possessing the contexts.

2.1.2 Scenario 2

In the second scenario, pAR receives a Context Transfer Request (CT-Req), described in Section 2.5, message from nAR. The nAR itself generates the CT-Req message as a result of receiving the CTAR message, or, alternatively, from receiving a context transfer trigger. In the CT-Req message, nAR supplies the MN's previous IP address, the FPTs for the feature contexts to be transferred, the sequence number from the CTAR, and the authorization token from the CTAR. In response to CT-Req message, pAR transmits a Context Transfer Data (CTD) message that includes the MN's previous IP address and feature contexts. When it receives a corresponding CTD message, nAR may generate a CTD Reply (CTDR) message to report the status of processing the received contexts. The nAR installs the contexts once it has received them from the pAR.

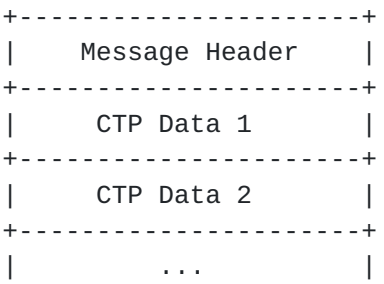
2.2 Context Transfer Message Format

A CTP message consists of a message-specific header and one or more data blocks. Data blocks may be bundled together in order to ensure a more efficient transfer. On the inter-AR interface, SCTP is used so fragmentation should not be a problem. On the MN-AR interface, the total packet size, including transport protocol and IP protocol headers SHOULD be less than the path MTU, in order to avoid packet fragmentation. Each message contains a three bit version number field in the low order octet, along with the 5 bit message type code. This specification only applies to Version 1 of the protocol, and the therefore version number field MUST be set to 0x1. If future revisions of the protocol make binary incompatible changes, the version number number MUST be incremented.

2.3 Context Types

Contexts are identified by FPT code, which is a 16-bit unsigned integer. The meaning of each context type is determined by a specification document and the context type numbers are to be tabulated in a registry maintained by IANA [IANA], and handled according to the message specifications in this document. The instantiation of each context by nAR is determined by the messages in

this document along with the specification associated with the particular context type. The following diagram illustrates the general format for CTP messages:

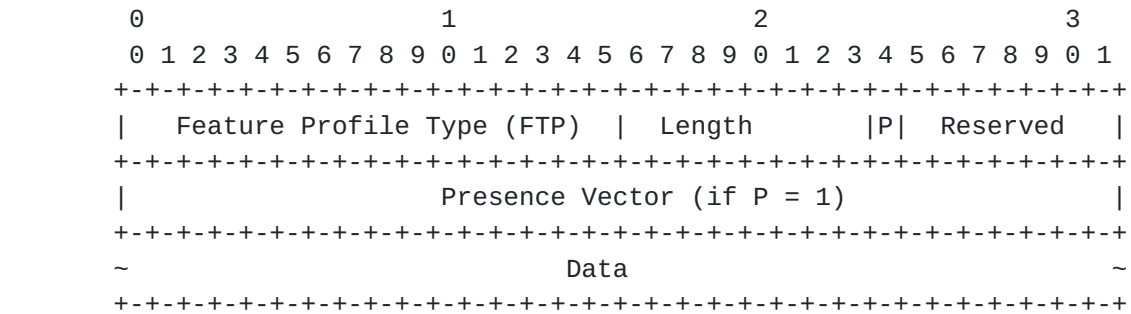


Each context type specification contains the following details:

- Number, size (in bits), and ordering of data fields in the state variable vector which embodies the context.
- Default values (if any) for each individual datum of the context state vector.
- Procedures and requirements for creating a context at a new access router, given the data transferred from a previous access router, and formatted according to the ordering rules and date field sizes presented in the specification.
- If possible, status codes for success or failure related to the context transfer. For instance, a QoS context transfer might have different status codes depending on which elements of the context data failed to be instantiated at nAR.

2.4 Context Data Block (CTB)

The Context Data Block (CTB) is used both for request and response operation. When a request is constructed, only the first 4 octets are typically necessary (See CTAR below). When used for transferring the actual feature context itself, the context data is present, and sometimes the presence vector is present.



Feature Profile Type

16 bit integer, assigned by IANA, indicating the type of data

	included in the Data field
Length	Message length in units of 8 octet words.
'P' bit	0 = No presence vector 1 = Presence vector present.
Reserved	Reserved for future use. Set to zero by the sender.
Data	Context type-dependent data, whose length is defined by the Length Field. If the data is not 64-bit aligned, the data field is padded with zeros.

The Feature Profile Type (FPT) code indicates the type of data in the data field. Typically, this will be context data but it might be an error indication. The 'P' bit specifies whether or not the "presence vector" is used. When the presence vector is in use, the Presence Vector is interpreted to indicate whether particular data fields are present (and containing non-default values). The ordering of the bits in the presence vector is the same as the ordering of the data fields according to the context type specification, one bit per data field regardless of the size of the data field. The Length field indicates the size of the CTB in 8 octet words including the first 4 octets starting from FPT.

Notice that the length of the context data block is defined by the sum of lengths of each data field specified by the context type specification, plus 4 octets if the 'P' bit is set, minus the accumulated size of all the context data that is implicitly given as a default value.

2.5 Messages

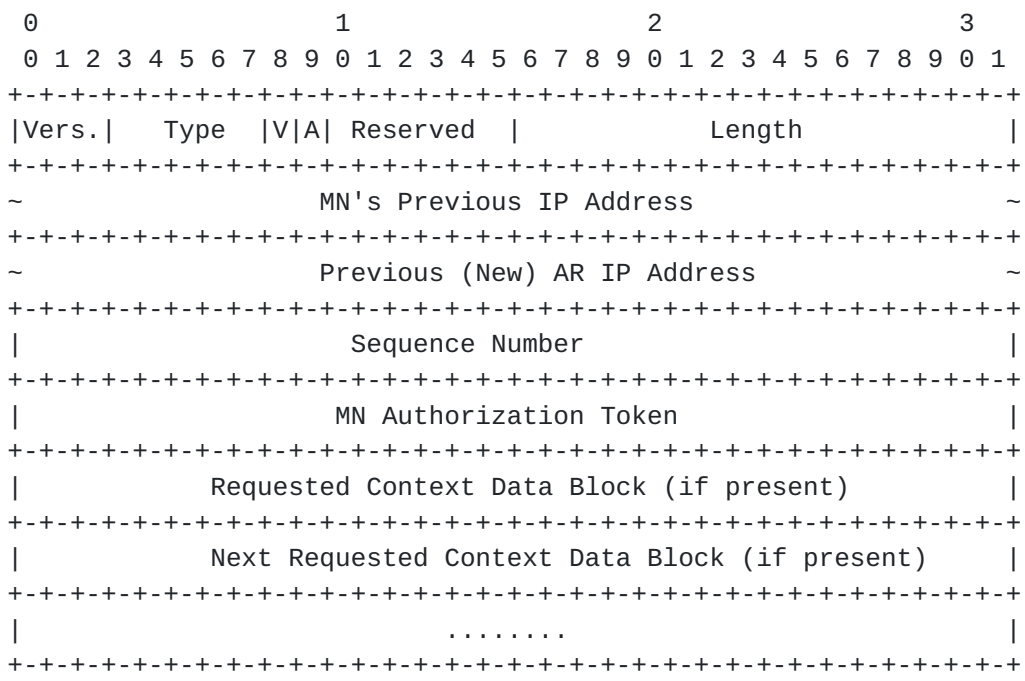
In this section, the CTP messages are defined. The MN for which context transfer protocol operations are undertaken is always identified by its previous IP access address. At any time, only one context transfer operation per MN may be in progress so that the CTDR message unambiguously identifies which CTD message is acknowledged simply by including the MN's identifying previous IP address. The 'V' flag indicates whether the IP addresses are IPv4 or IPv6.

2.5.1 Context Transfer Activate Request (CTAR) Message

This message is always sent by MN to nAR to request context transfer. Even when the MN does not know if contexts need to be transferred,

the MN sends the CTAR message. If an acknowledgement for this message is needed, the MN sets the 'A' flag to 1; otherwise the MN does not expect an acknowledgement. This message may include a list of FPTs that require transfer.

The MN may also send this message to pAR while still connected to pAR. In such a case, the MN includes the nAR's IP address; otherwise, if the message is sent to nAR, the pAR address is sent. The MN MUST set the sequence number to the same value for the message sent on both pAR and nAR so pAR can determine whether to use a cached message.



Vers. Version number of CTP protocol = 0x1

Type CTAR = 0x1

'V' flag When set to '0', IPv6 addresses.
When set to '1', IPv4 addresses.

'A' bit If set, the MN requests an acknowledgement.

Reserved Set to zero by the sender, ignored by the receiver.

Length Message length in units of octets.

MN's Previous IP Address Field contains either:

	IPv4 Address as defined in [RFC 791], 4 octets. IPv6 Address as defined in [RFC 2373], 16 octets.
nAR / pAR IP Address	Field contains either: IPv4 Address as defined in [RFC 791], 4 octets. IPv6 Address as defined in [RFC 2373], 16 octets.
Sequence Number	A value used to identify requests and acknowledgements (see Section 3.2).
Authorization Token	An unforgeable value calculated as discussed below. This authorizes the receiver of CTAR to perform context transfer.
Context Block	Variable length field defined in Section 2.4.

If no context types are specified, all contexts for the MN are requested.

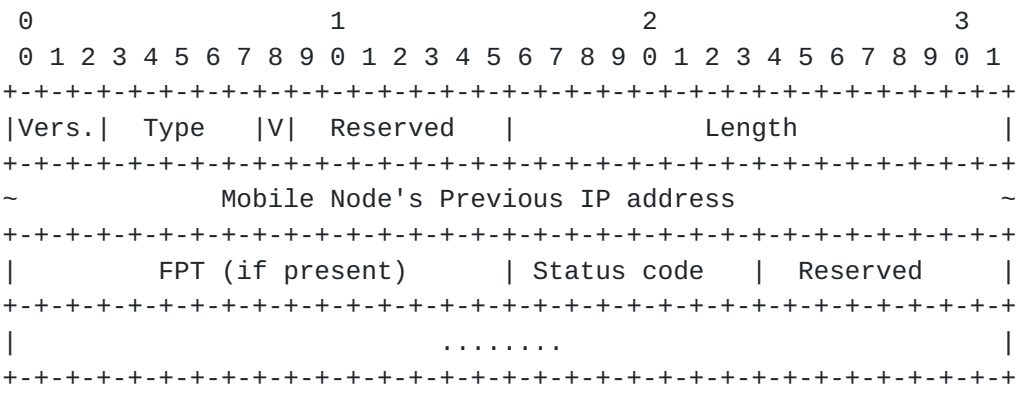
The Authorization Token is calculated as:

```
First (32, HMAC_SHA1
        (Key, (Previous IP address | Sequence Number | CTBs)))
```

where Key is a shared secret between the MN and pAR, and CTBs is a concatenation of all the Context Data Blocks specifying the contexts to be transfered which are included in the CTAR message.

2.5.2 Context Transfer Activate Acknowledge (CTAA) Message

This is an informative message sent by the receiver of CTAR to the MN to acknowledge a CTAR message. Acknowledgement is optional, depending on whether the MN requested it. This message may include a list of FPTs that were not transferred successfully.



Vers. Version number of CTP protocol = 0x1

Type CTAA = 0x2

'V' flag When set to '0', IPv6 addresses.
When set to '1', IPv4 addresses.

Reserved Set to zero by the sender and ignored by the receiver.

Length Message length in units of octets.

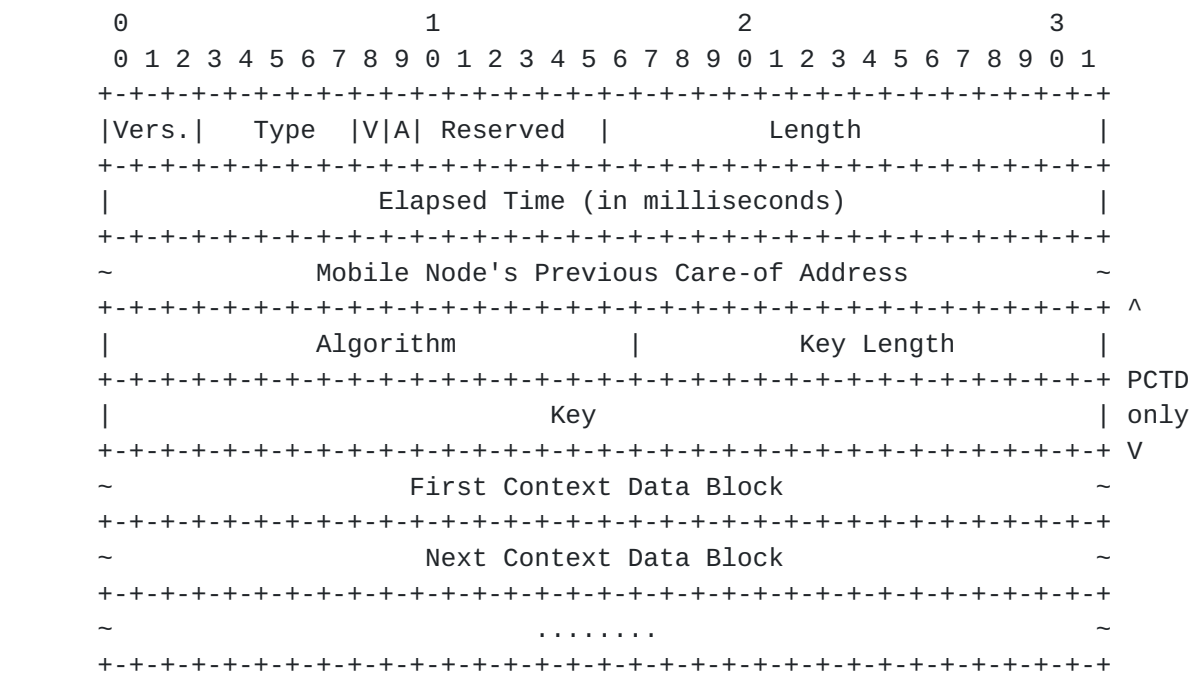
MN's Previous IP Address Field contains either:
IPv4 Address as defined in [RFC 791], 4 octets.
IPv6 Address as defined in [RFC 2373], 16 octets.

FPT 16 bit unsigned integer, listing the FTP that was not successfully transferred.

Status Code An octet, containing failure reason.

2.5.3 Context Transfer Data (CTD) Message

Sent by pAR to nAR, and includes feature data (CTP data). This message handles predictive as well as normal CT. An acknowledgement flag, 'A', included in this message indicates whether a reply is required by pAR.



Vers. Version number of CTP protocol = 0x1

Type CTD = 0x3 (Context Transfer Data)
PCTD = 0x4 (Predictive Context Transfer Data)

'V' flag When set to '0', IPv6 addresses.
When set to '1', IPv4 addresses.

'A' bit When set, the pAR requests an acknowledgement.

Length Message length in units of octets.

Elapsed Time The number of milliseconds since the transmission of the first CTD message for this MN.

MN's Previous IP Address Field contains either:
IPv4 Address as defined in [RFC 791], 4 octets.
IPv6 Address as defined in [RFC 2373], 16 octets.

Algorithm Algorithm for carrying out the computation of the MN Authorization Token. Currently only 1 algorithm is defined, HMAC_SHA1 = 1.

Key Length	Length of key, in octets.
Key	Shared key between MN and AR for CTP.
Context Data Block	The Context Data Block (see Section 2.4).

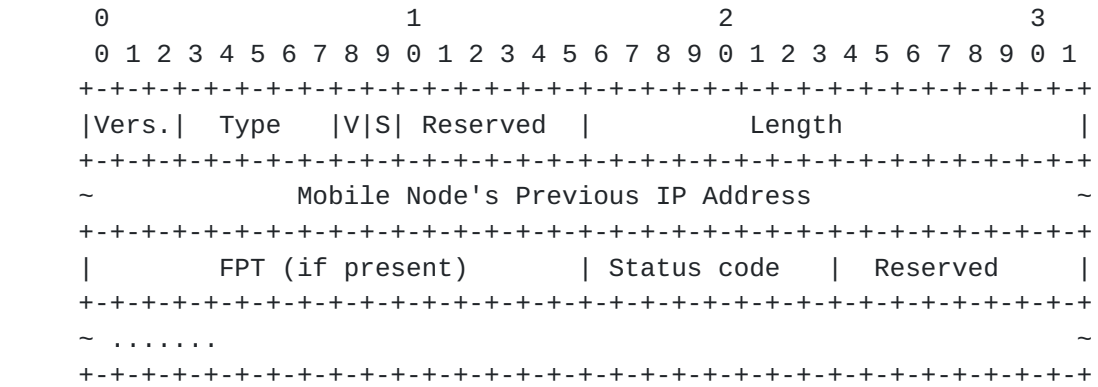
When CTD is sent predictively, the supplied parameters including the algorithm, key length and the key itself, allowing nAR to compute a token locally and verify against the token present in the CTAR message. This material is also sent if the pAR receives a CTD message with a null Authorization Token, indicating that the CT-Req message has been sent before the nAR received the CTAR message. CTD MUST be protected by IPsec, see Section 6.

As described previously, the algorithm for carrying out the computation of the MN Authorization Token is HMAC_SHA1. The token authentication calculation algorithm is described in Section 2.5.1.

For predictive handover, the pAR SHOULD keep track of the CTAR sequence number and cache the CTD message until receiving either a CTDR message for the MN's previous IP address from the pAR, indicating that the context transfer was successful, or until CT_MAX_HANDOVER_TIME expires. The nAR MAY send a CT-Req message containing the same sequence number if the predictive CTD message failed to arrive or the context was corrupted, In that case, the nAR sends a CT-Req message with a matching sequence number and pAR can resend the context.

2.5.4 Context Transfer Data Reply (CTDR) Message

This message is sent by nAR to pAR depending on the value of the 'A' flag in CTD. Indicates success or failure.

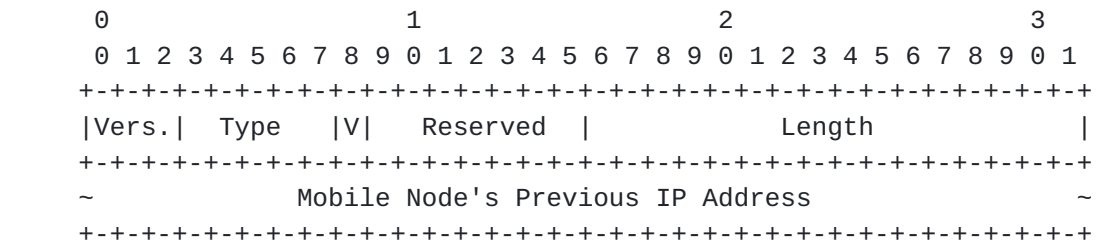


Vers.	Version number of CTP protocol = 0x1
Type	CTDR = 0x5 (Context Transfer Data)

'V' flag	When set to '0', IPv6 addresses. When set to '1', IPv4 addresses.
'S' bit	When set to one, this bit indicates that all feature contexts sent in CTD or PCTD were received successfully.
Reserved	Set to zero by the sender and ignored by the receiver.
Length	Message length in units of octets.
MN's Previous IP Address Field contains either:	IPv4 Address as defined in [RFC 791], 4 octets. IPv6 Address as defined in [RFC 2373], 16 octets.
Status Code	A context-specific return value, zero for success, nonzero when 'S' is not set to one.
FPT	16 bit unsigned integer, listing the FTP that is being acknowledged.

2.5.5 Context Transfer Cancel (CTC) Message

If transferring a context cannot be completed in a timely fashion, then nAR may send CTC to pAR to cancel an ongoing CT process.



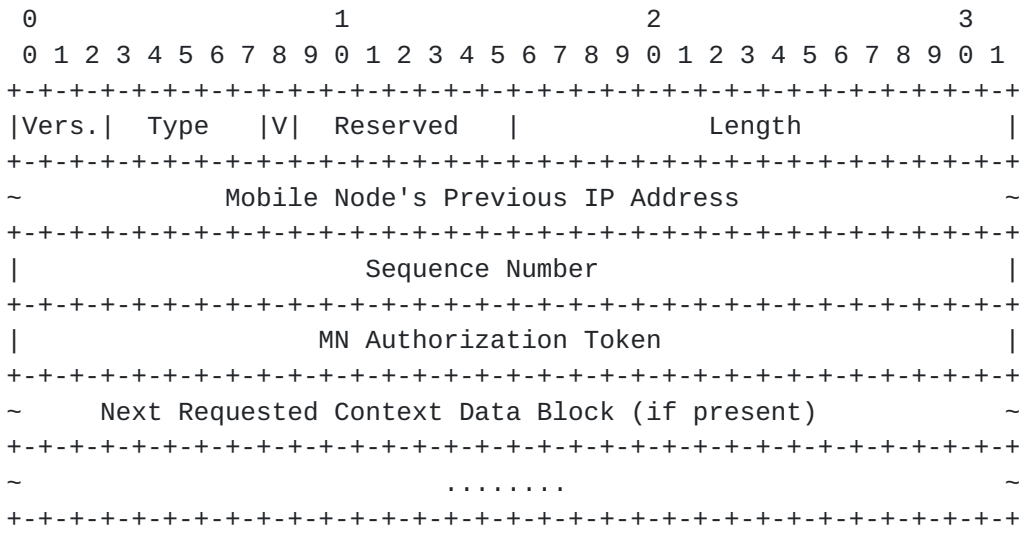
Vers.	Version number of CTP protocol = 0x1
Type	CTC = 0x6 (Context Transfer Cancel)
Length	Message length in units of octets.
'V' flag	When set to '0', IPv6 addresses. When set to '1', IPv4 addresses.
Reserved	Set to zero by the sender and ignored by

the receiver.

MN's Previous IP Address Field contains either:
IPv4 Address as defined in [RFC 791],
4 octets.
IPv6 Address as defined in [RFC 2373],
16 octets.

2.5.6 Context Transfer Request (CT-Req) Message

Sent by nAR to pAR to request start of context transfer. This message is sent as a response to CTAR message from the MN. The fields following the Previous IP address of the MN are included verbatim from the CTAR message.



Vers. Version number of CTP protocol = 0x1

Type CTREQ = 0x7 (Context Transfer Request)

'V' flag When set to '0', IPv6 addresses.
When set to '1', IPv4 addresses.

Reserved Set to zero by the sender and ignored by the receiver.

Length Message length in units of octets.

MN's Previous IP Address Field contains either:
IPv4 Address as defined in [RFC 791],
4 octets.
IPv6 Address as defined in [RFC 2373],

16 octets.

Sequence Number
: Copied from the CTAR message, allows the pAR to distinguish requests for previously sent context.

MN's Authorization Token
: An unforgeable value calculated as discussed in Section 2.5.1. This authorizes the receiver of CTAR to perform context transfer. Copied from CTAR.

Context Data Request Block
: A request block for context data, see Section 2.4.

The sequence number is used by pAR to correlate a request for previously transmitted context. In predictive transfer, if the MN sends CTAR prior to handover, pAR pushes context to nAR using CTD. If the CTD fails, the nAR will send CT-Req with the same sequence number, allowing the pAR to distinguish which context to resend. pAR drops the context after CTP_MAX_TRANSFER_TIME. The sequence number is not used in reactive transfer.

For predictive transfer the pAR sends the keying material and other information necessary to calculate the Authorization Token, with no CT-Req message necessary. For reactive transfer, if the nAR receives a context transfer trigger but has not yet received the CTAR message with the authorization token, the Authorization Token field in CT-Req is set to zero. The pAR interprets this as an indication to include the keying material and other information necessary to calculate the Authorization Token, and includes this material into the CTD message as if the message were being sent due to predictive transfer. This provides nAR with the information it needs to calculate the authorization token when the MN sends CTAR.

3. Transport

3.1 Inter-Router Transport

Since the types of access networks in which CTP might be useful are not today deployed or, if they have been deployed, have not been extensively measured, it is difficult to know whether congestion will be a problem for CTP. Part of the research task in preparing CTP for consideration as a candidate for possible standardization is to quantify this issue. However, in order to avoid potential interference with production applications should a prototype CTP

deployment involve running over the public Internet, it seems prudent to recommend a default transport protocol that accommodates congestion. In addition, since the feature context information has a definite lifetime, the transport protocol must accommodate flexible retransmission, so stale contexts that are held up by congestion are dropped. Finally, because the amount of context data can be arbitrarily large, the transport protocol should not be limited to a single packet, or require implementing a custom fragmentation protocol.

These considerations argue that implementations of CTP MUST support and prototype deployments of CTP SHOULD use Stream Control Transport Protocol (SCTP) [SCTP] for the transport protocol on the inter-router interface, especially if deployment over the public Internet is contemplated. SCTP supports congestion control, fragmentation, and partial retransmission based on a programmable retransmission timer. SCTP also supports many advanced and complex features, such as multiple streams and multiple IP addresses for failover, that are not necessary for experimental implementation and prototype deployment of CTP. In this specification, the use of such SCTP features is not recommended at this time.

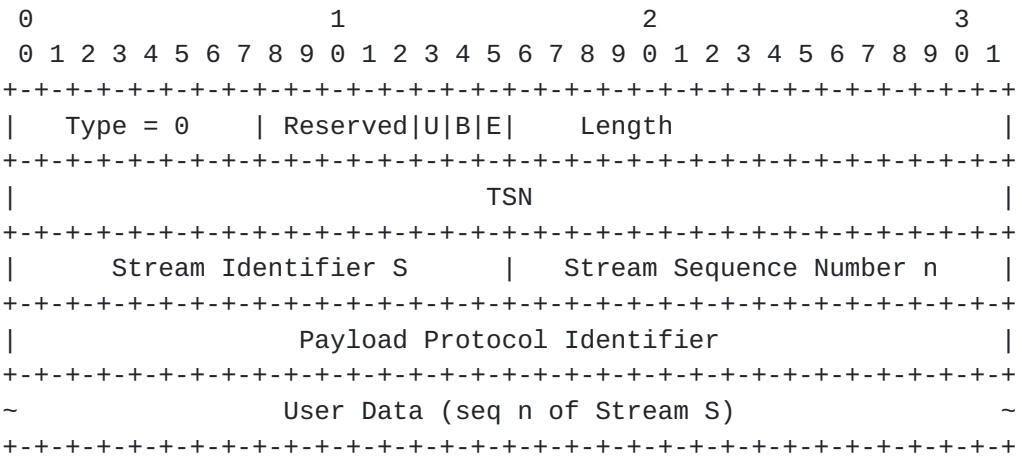
The SCTP Payload Data Chunk carries the context transfer protocol messages. The User Data part of each SCTP message contains an appropriate context transfer protocol message defined in this document. The messages sent using SCTP are CTD (Section 2.5.3), CTDR (Section 2.5.4), CTC (Section 2.5.5) and CT-Req (Section 2.5.6). In general, each SCTP message can carry feature contexts belonging to any MN. If the SCTP checksum calculation fails, the nAR returns the BAD_CHECKSUM error code in a CTDR message.

A single stream is used for context transfer without in-sequence delivery of SCTP messages. Each message corresponds to a single MN's feature context collection. A single stream provides simplicity. Use of multiple streams to prevent head-of-line blocking is for future study. Having unordered delivery allows the receiver to not block for in-sequence delivery of messages that belong to different MNs. The Payload Protocol Identifier in the SCTP header is 'CTP'. Inter-router CTP uses the Seamoby SCTP port [IANA].

Timeliness of the context transfer information SHOULD be accommodated by setting the SCTP maximum retransmission value to CT_MAX_TRANSFER_TIME in order to accommodate the maximum acceptable handover delay time, and the AR SHOULD be configured with CT_MAX_TRANSFER_TIME to accommodate the particular wireless link technology and local wireless propagation conditions. SCTP message bundling SHOULD be turned off in order to reduce any extra delay in sending messages. Within CTP, the nAR SHOULD estimate the retransmit

timer from the receipt of the first fragment of a CTP message and avoid processing any IP traffic from the MN until either context transfer is complete or the estimated retransmit timer expires. If both routers support PR-SCTP [PR-SCTP], then PR-SCTP SHOULD be used. PR-SCTP modifies the lifetime parameter of the Send() operation defined in Section 10.1 E in [SCTP] so that it applies to retransmits as well as transmits; that is, in PR-SCTP if the lifetime expires and the data chunk has not been acknowledged, the transmitter stops retransmitting, whereas in the base protocol the data would be retransmitted until acknowledged or the connection timed out.

The format of Payload Data Chunk taken from [SCTP] is shown in the following diagram.



'U' bit The Unordered bit. MUST be set to 1 (one).
'B' bit The Beginning fragment bit. See [SCTP].

'E' bit The Ending fragment bit. See [SCTP].

TSN Transmission Sequence Number. See [SCTP].

Stream Identifier S
Identifies the context transfer protocol stream.

Stream Sequence Number n
Since the 'U' bit is set to one, the receiver ignores this number. See [SCTP].

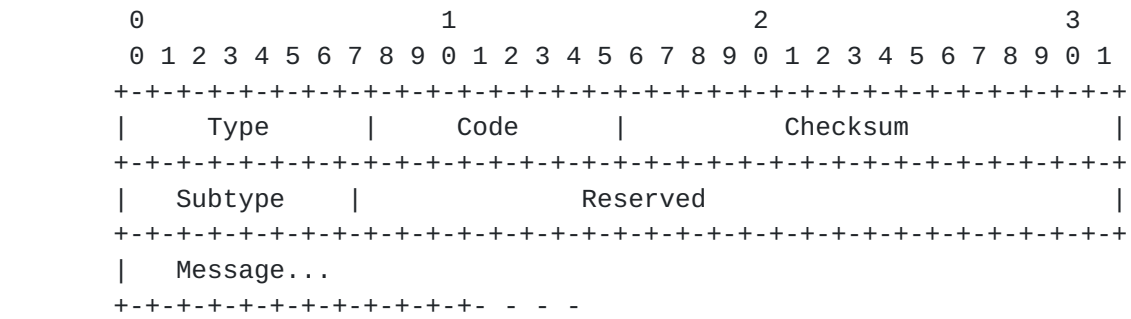
Payload Protocol Identifier
Set to 'CTP' (see [IANA]).

User Data Contains the context transfer protocol messages.

If a CTP deployment will never run over the public Internet, and it is known that congestion is not a problem in the access network, alternative transport protocols MAY be appropriate vehicles for experimentation. An example is piggybacking CTP messages on top of handover signaling for routing, such as provided by FMIPv6 in ICMP [FMIPv6]. Implementations of CTP MAY support ICMP for such purposes. If such piggybacking is used, an experimental message extension for the protocol on which CTP is piggybacking MUST be designed. Direct deployment on top of a transport protocol for experimental purposes is also possible, in that case, the researcher MUST be careful to accommodate good Internet transport protocol engineering practices, including using retransmits with exponential backoff.

3.2 MN-AR Transport

The MN-AR interface MUST implement and SHOULD use ICMP for transport of the CTAR and CTAA messages. Because ICMP contains no provisions for retransmitting packets if signaling is lost, the CTP protocol incorporates provisions for improving transport performance on the MN-AR interface. The MN and AR SHOULD limit the number of context data block identifiers included in the CTAR and CTAA messages so that the message will fit into a single packet, since ICMP has no provision for fragmentation above the IP level. CTP uses the Experimental Mobility ICMP type [IANA]. The ICMP message format for CTP messages is as follows:



IP Fields:

Source Address — An IP address assigned to the sending interface.

Destination Address — An IP address assigned to the receiving interface.

Hop Limit 255

ICMP Fields:

Type	Experimental Mobility Type (To be assigned by IANA, for IPv4 and IPv6, see [IANA])
Code	0
Checksum	The ICMP checksum.
Sub-type	The Experimental Mobility ICMP subtype for CTP, see [IANA].
Reserved	Set to zero by the sender and ignored by the receiver.
Message	The body of the CTAR or CTAA message.

CTAR messages for which a response is requested but which fail to elicit a response are retransmitted. The initial retransmission occurs after a CTP_REQUEST_RETRY wait period. Retransmissions MUST be made with exponentially increasing wait intervals (doubling the wait each time). CTAR messages should be retransmitted until either a response (which might be an error) has been obtained, or until CTP_RETRY_MAX seconds after the initial transmission.

MNs SHOULD generate the sequence number in the CTAR message randomly, and, for predictive transfer, MUST use the same sequence number in a CTAR to the nAR as for the pAR. An AR MUST ignore the CTAR if it has already received one with the same sequence number and MN IP address.

Implementations MAY, for research purposes, try other transport protocols. Examples are the definition of a Mobile IPv6 Mobility Header [MIPv6] for use with the FMIPv6 Fast Binding Update [FMIPv6] to allow bundling of both routing change and context transfer signaling from the MN to AR, or definition of a UDP protocol instead of ICMP. If such implementations are done, they should abide carefully by good Internet transport engineering practices and be used for prototype and demonstration purposes only. Deployment on large scale networks should be avoided until the transport characteristics are well understood.

4. Error Codes and Constants

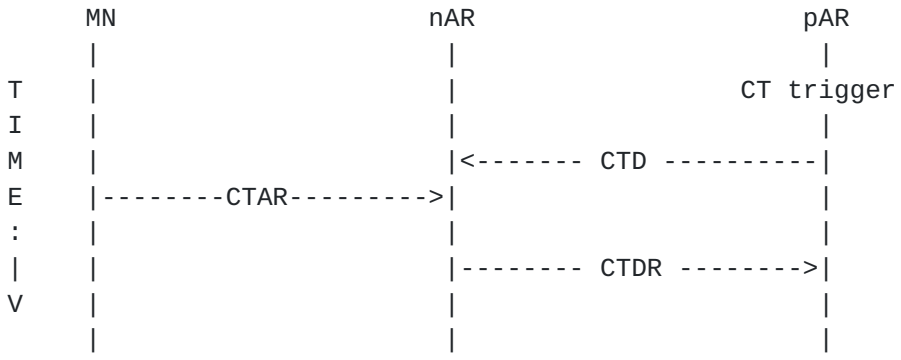
Error Code	Section	Value	Meaning

BAD_CHECKSUM	3.1	0x01	Error code if the SCTP checksum fails.

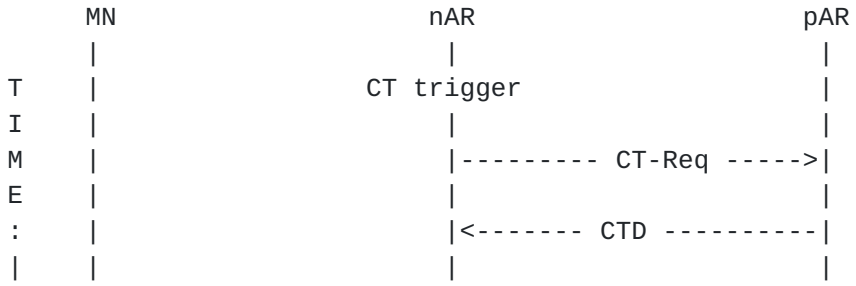
Constant	Section	Default Value	Meaning
CT_REQUEST_RATE	6.3	10 requests/ sec.	Maximum number of CTAR messages before AR institutes rate limiting.
CT_MAX_TRANSFER_TIME	3.1	200 ms	Maximum amount of time pAR should wait before aborting the transfer.
CT_REQUEST_RETRY	3.2	2 seconds	Wait interval before initial retransmit on MN-AR interface.
CT_RETRY_MAX	3.2	15 seconds	Give up retrying on MN-AR interface.

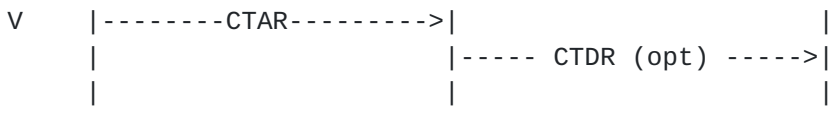
5. Examples and Signaling Flows

5.1 Network controlled, Initiated by pAR, Predictive



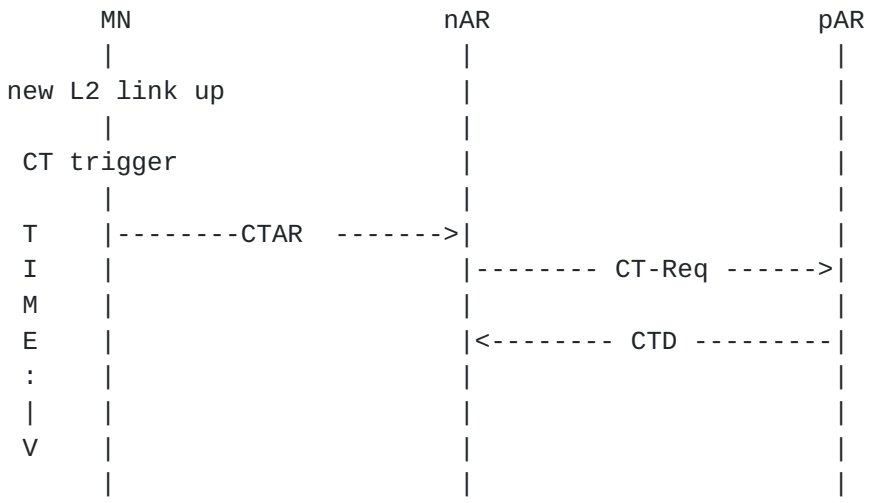
5.2 Network controlled, initiated by nAR, Reactive





5.3 Mobile controlled, Predictive New L2 up/old L2 down

CTAR request to nAR



It is for future study whether the nAR sends the MN a CTAR reject if CT is not supported.

6. Security Considerations

At this time, the threats to IP handover in general and context transfer in particular are incompletely understood, particularly on the MN to AR link, and mechanisms for countering them are not well defined. Part of the experimental task in preparing CTP for eventual standards track will be to better characterize threats to context transfer and design specific mechanisms to counter them. This section provides some general guidelines about security based on discussions among the Design Team and Working Group members.

6.1. Threats.

The Context Transfer Protocol transfers state between access routers. If the MNs are not authenticated and authorized before moving on the network, there is a potential for masquerading attacks to shift state between ARs, causing network disruptions.

Additionally, DoS attacks can be launched from MNs towards the access routers by requesting multiple context transfers and then disappearing. Finally, a rogue access router could flood mobile

nodes with packets, attempting DoS attacks, and issue bogus context transfer requests to surrounding routers.

Consistency and correctness in context transfer depend on interoperable feature context definitions and how CTP is utilized for a particular application. For some considerations regarding consistency and correctness that have general applicability but are articulated in the context of AAA context transfer, please see [EAP].

6.2. Access Router Considerations

The CTP inter-router interface relies on IETF standardized security mechanisms for protecting traffic between access routers, as opposed to creating application security mechanisms. IPsec MUST be supported between access routers.

In order to avoid the introduction of additional latency due to the need for establishment of a secure channel between the context transfer peers (ARs), the two ARs SHOULD establish such a secure channel in advance. The two access routers need to engage in a key exchange mechanisms such as IKE [RFC2409], establish IPSec SAs, defining the keys, algorithms and IPSec protocols (such as ESP) in anticipation for any upcoming context transfer. This will save time during handovers that require secure transfer. Such SAs can be maintained and used for all upcoming context transfers between the two ARs. Security should be negotiated prior to the sending of context.

Access Routers MUST implement IPsec ESP [ESP] in transport mode with non-null encryption and authentication algorithms to provide per-packet authentication, integrity protection and confidentiality, and MUST implement the replay protection mechanisms of IPsec. In those scenarios where IP layer protection is needed, ESP in tunnel mode SHOULD be used. Non-null encryption should be used when using IPSec ESP. Strong security on the inter-router interface is required to protect against attacks by rogue routers, and to ensure confidentiality on the context transfer authorization key in predicative transfer.

The details of IKE key exchange and other details of the IPsec security associations between routers are to be determined as part of the research phase associated with finalizing the protocol for standardization. Prior to standardization, these details must be determined. Other working groups are currently working on general security for routing protocols. Ideally, a solution for CTP will be based on this work, if possible, in order to minimize operational configuration of routers for different protocols. Requirements for CTP will be brought to the appropriate IETF routing protocol security

working groups for consideration.

6.3 Mobile Node Considerations

The CTAR message requires the MN and AR to possess a shared secret key in order to calculate the authorization token. Validation of this token MUST precede context transfer or installation of context for the MN, removing the risk that an attacker could cause an unauthorized transfer. How the shared key is established is out of scope of the current specification. If both the MN and AR know certified public keys of the other party, Diffie-Helman can be used to generate a shared secret [RFC2631]. If an AAA protocol of some sort is run for network entry, the shared key can be established using that protocol [PerkCal04].

If predictive context transfer is used, the shared key for calculating the authorization token is transferred between ARs. A transfer of confidential material of this sort poses certain security risks, even if the actual transfer itself is confidential and authenticated, as is the case for inter-router CTP. The more entities know the key, the more likely a compromise may occur. In order to mitigate this risk, nAR MUST discard the key immediately after using it to validate the authorization token. The MN MUST establish a new key with the AR for future CTP transactions. The MN and AR SHOULD exercise care in using a key established for other purposes for also authorizing context transfer. It is RECOMMENDED that a separate key be established for context transfer authorization.

Replay protection on the MN-AR protocol is provided by limiting the time period in which context is maintained. For predictive transfer, the pAR receives a CTAR message with a sequence number, transfers the context along with the authorization token key, then drops the context and the authorization token key immediately upon completion of the transfer. For reactive transfer, the nAR receives the CTAR, requests the context, including the sequence number and authorization token from the CTAR which allows the pAR to check whether the transfer is authorized. The pAR drops the context and authorization token key after the transfer has been completed. The pAR and nAR ignore any requests containing the same MN IP address if an outstanding CTAR or CTD message is unacknowledged and has not timed out. After the key has been dropped, any attempt at replay will fail because the authorization token fails to validate. The AR MUST NOT reuse the key for any MN, including the same MN as originally possessed the key.

DoS attacks on the MN-AR interface can be limited by having the AR rate limit the number of CTAR messages it processes. The AR SHOULD limit the number of CTAR messages to CT_REQUEST_RATE. If the request

exceeds this rate, the AR SHOULD randomly drop messages until the rate is established. The actual rate SHOULD be configured on the AR to match the maximum number of handovers that the access network is expected to support.

7. IANA Considerations

Instructions for IANA allocations are included in [IANA].

8. Acknowledgements & Contributors

This document is the result of a design team formed by the Working Group chairs of the SeaMoby working group. The team included John Loughney, Madjid Nakhjiri, Rajeev Koodli and Charles Perkins.

Contributors to the Context Transfer Protocol review are Basavaraj Patil, Pekka Savola, and Antti Tuominen.

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Appendix A. Timing and Trigger Considerations

Basic Mobile IP handover signaling can introduce disruptions to the services running on top of Mobile IP, which may introduce unwanted latencies that practically prohibit its use for certain types of

services. Mobile IP latency and packet loss is being optimized through several alternative procedures, such as Fast Mobile IP [FMIPv6] and Low Latency Mobile IP [LLMIP].

Feature re-establishment through context transfer should contribute zero (optimally) or minimal extra disruption of services in conjunction to handovers. This means that the timing of context transfer SHOULD be carefully aligned with basic Mobile IP handover events, and with optimized Mobile IP handover signaling mechanisms, as those protocols become available.

Furthermore, some of those optimized mobile IP handover mechanisms may provide more flexibility in choosing the timing and order for transfer of various context information.

Appendix B. Multicast Listener Context Transfer

In the past, credible proposals have been made in the Seamoby Working Group and elsewhere for using context transfer to speed handover of authentication, authorization, and accounting context, distributed firewall context, PPP context, and header compression context. Because the Working Group was not chartered to develop context profile definitions for specific applications, none of the drafts submitted to Seamoby were accepted as Working Group items. At this time, work continues to develop a context profile definition for RFC 3095 header compression context [RFC3095] and to characterize the performance gains obtainable by using header compression, but the work is not yet complete. In addition, there are several commercial wireless products that reportedly use non-standard, non-interoperable context transfer protocols, though none is as yet widely deployed.

As a consequence, it is difficult at this time to point to a solid example of how context transfer could result in a commercially viable, widely deployable, interoperable benefit for wireless networks. This is one reason why CTP is being proposed as an Experimental protocol, rather than Standards Track. However, it nevertheless seems valuable to have a simple example that shows how handover could benefit from using CTP. The example we consider here is transferring IPv6 MLD state [RFC2710]. MLD state is a particularly good example because every IPv6 node must perform at least one MLD messaging sequence on the wireless link to establish itself as an MLD listener prior to performing router discovery [RFC2461] or duplicate address detection [RFC2462] or before sending/receiving any application-specific traffic (including Mobile IP handover signaling, if any). The node must subscribe to the Solicited Node Multicast Address as soon as it comes up on the link. Any application-specific multicast addresses must be re-established as well. Context transfer can significantly speed up re-establishing multicast state by allowing the nAR

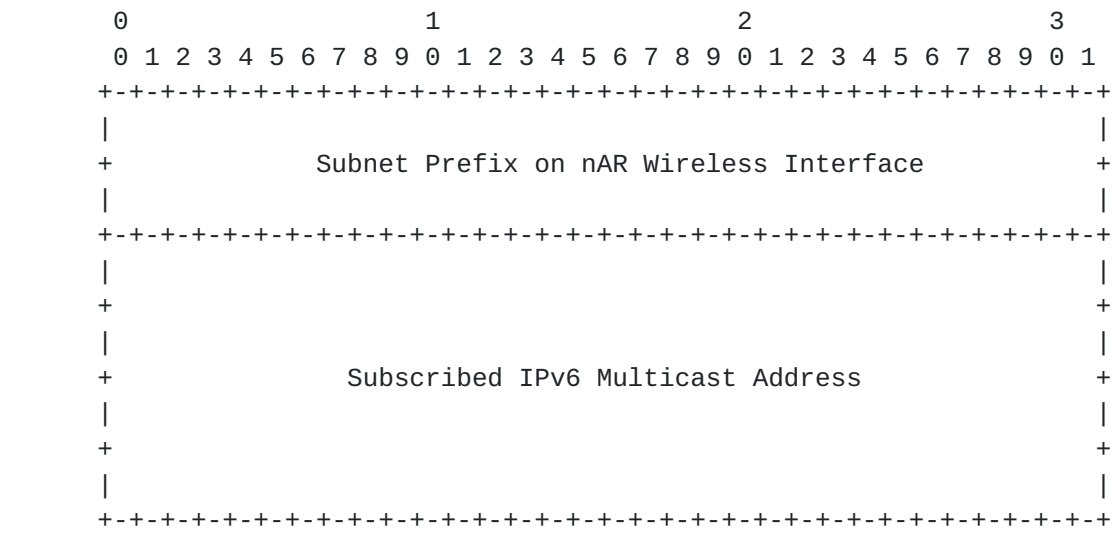
to initialize MLD for a node that just completed handover without any MLD signaling on the new wireless link. The same approach could be used for transferring multicast context in IPv4.

An approximate quantitative estimate for the amount of savings in handover time can be obtained as follows. MLD messages are 24 octets, to which the headers must be added, because there is no header compression on the new link, with IPv6 header being 40 octets, and a required Router Alert Hop-by-Hop option being 8 octets including padding. The total MLD message size is 72 octets per subscribed multicast address. RFC 2710 recommends that nodes send 2 to 3 MLD Report messages per address subscription, since the Report message is unacknowledged. Assuming 2 MLD messages sent for a subscribed address, the MN would need to send 144 octets per address subscription. If MLD messages are sent for both the All Nodes Multicast address and the Solicited Node Multicast address for the node's link local address, a total of 288 octets are required when the node hands over to the new link. Note that some implementations of IPv6 optimize by not sending an MLD message for the All Nodes Multicast Address, since the router can infer that at least one node is on the link (itself) when it comes up and always will be, but for purposes of this calculation, we assume that the IPv6 implementation is conformant and that the message is sent. The amount of time required for MLD signaling will, of course, depend on the per node available wireless link bandwidth, but some representative numbers can be obtained by assuming bandwidths of 20 kbps or 100 kbps. With these two bit rates, the savings from not having to perform the pre-router discovery messages are 115 msec. and 23 msec., respectively. If any application-specific multicast addresses are subscribed, the amount of time saved could be substantially more.

This example might seem a bit contrived because MLD isn't used in the 3G cellular protocols and wireless local area network protocols typically have enough bandwidth, if radio propagation conditions are optimal, so sending a single MLD message might not be viewed as such a performance burden. An example of a wireless protocol where MLD context transfer might be useful is IEEE 802.15.1 (Bluetooth)[BT]. IEEE 802.15.1 has two IP "profiles": one with and one without PPP. The profile without PPP would use MLD. The 802.15.1 protocol has a maximum bandwidth of about 800 kbps, shared between all nodes on the link, so a host on a moderately loaded 802.15.1 access point could experience the kind of bandwidth described in the previous paragraph. In addition 802.15.1 handover times typically run upwards of a second or more because the host must resynchronize its frequency hopping pattern with the access point, so anything the IP layer could do to alleviate further delay would be beneficial.

The context-specific data field for MLD context transfer included in

the CTP Context Data Block message for a single IPv6 multicast address has the following format:



The Subnet Prefix on nAR Wireless Interface field contains a subnet prefix that identifies the interface on which multicast routing should be established. The Subscribed IPv6 Multicast Address field contains the multicast address for which multicast routing should be established.

The pAR sends one MLD context block per subscribed IPv6 multicast address.

No changes are required in the MLD state machine.

Upon receipt of a CTP Context Data Block for MLD, the state machine takes the following actions:

- If the router is in the No Listeners present state on the wireless interface on which the Subnet Prefix field in the Context Data Block is advertised, it transitions into the Listeners Present state for the Subscribed IPv6 Multicast Address field in the Context Data Block. This transition is exactly the same as if the router had received a Report message.

- If the router is in the Listeners present state on that interface, it remains in that state but restarts the timer, as if it had received a Report message.

If more than one MLD router is on the link, a router receiving an MLD Context Data Block SHOULD send the block to the other routers on the link. If wireless bandwidth is not an issue, the router MAY instead send a proxy MLD Report message on the wireless interface that

advertises the Subnet Prefix field from the Context Data Block. Since MLD routers do not keep track of which nodes are listening to multicast addresses, only whether a particular multicast address is being listened to, proxying the subscription should cause no difficulty.

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