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        **Deterministic Fast Router Advertisement Configuration**
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Abstract

   Neighbour Discovery forces routers responding to Router Solicitations
   to delay a random interval of 0-500 ms in order to prevent contention
   and bandwidth utilization by multiple responding routers.  Routers
   receiving solicitations may need to quickly send responding Router
   Advertisements faster than allowed in IPv6 Neighbour Discovery.

   In order to provide fast router response, Fast Router Advertisements

have been proposed, which do not randomly delay.  This document
describes an automatic arbitration and configuration mechanism to
allow hosts to securely agree on the relative ordering and delay of
their Fast Router Advertisements.


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1.  **Introduction**

   Existing standards require that hosts which respond to Router
   Solicitations introduce a random delay of 0-500ms before sending a
   Router Advertisement [2].

   The Fast RA draft [6] introduces the concept of a Fast Router
   Advertisement.  Fast Router advertisements provide the capability for
   a router to avoid performing the random delay before transmission,
   and send responses without the mean 250ms delay.

   Additionally, routers may wish to allow a small number of multicast
   Router Advertisements to configuring devices with similar delays.
   Extensions to FastRA which support multicast Router Advertisement are
   considered in this document (possibly to move elsewhere later).

   Fast Router Advertisement, as specified, only allows one host on a
   link to be a FastRA router.  Unless FastRA specified this limit,
   responses from more than one FastRA router would result in the same
   MAC contention which RFC 2461 sought to avoid.

   Unfortunately, while Fast RA is an effective way of providing fast
   response, it has no defined automated configuration mechanism to
   determine which router is the fastest, nor any method to provide
   router reselection in case a router is no longer able to provide fast
   responses.  This lack of a router reselection mechanism is seen a a
   clear stumbling block to FastRA's deployment.

   This document defines a secured mechanism relying on new
   Router-to-Router ICMPv6 messages to allow routers to make decisions
   about which router responds fastest, and additionally allows other
   routers to avoid random delays[5][2].  The new mechanism relies upon
   SEND-like security to determine trust-relationships between on-link
   routers, and test the reachability of existing routers.

   It allows automated reconfiguration in the case that routers join or
   leave the Fast Router set, and ensures that Fast Routers do not
   collide with each other by providing negotiated fixed delays between
   responding advertisements.

2.  **Terminology**

   The following terms are used throughout the document

   Bootstrapping Router: A router which has not yet determined its rank
      and delay for Fast Router Advertisement.

Deterministic Fast Router Advertisement Option (DetFRAO): An ICMPv6
    option indicating the Fast Router's participation in this
    protocol, as well as its rank and delay.  This option may appear
    in Router-to-Router Status-Requests and Status messages, as well
    as Router Solicitations and Advertisements.  The option's format
    is defined in [Section 4.2](#).

Fast Router: A router participating in this protocol and exchanging
    Deterministic Fast Router Advertisement Options in
    Router-to-Router messages.

Fast Router Advertisement: A response to a Router Solicitation which
    is not randomly delayed.  Please note that at a particular time, a
    Fast Advertising Router may advertise with a delay whose mean is
    slower than that defined by [2].  Even in this case, the response
    is still called a Fast Router Advertisement (or FastRA).

Fast Advertising Router List: A conceptual list where FastRA routers
    are sorted by a Ranking Score, and delays for various routers
    calculated.

Fastest Advertising Router: The router with Rank=1, which is able to
    transmit without delay.

Fixed Delay: The minimum amount of time which a Fast Advertising
    Router may delay before sending a Router Advertisement in response
    to a Router Solicitation.  Typically this is the delay used for
    Router Advertisement transmission.

Legacy Router: A router which responds to router solicitations using
    the algorithm defined in [section 6.2.6](#) of the IPv6 Neighbour
    Discovery RFC[2].

Multicast Fast Router Advertisement A Fast Router Advertisement sent
    to the all-nodes multicast address.  These advertisements have
    different parameters for their Token Bucket than a Unicast Fast
    Router Advertisement.

Rank: The position of the router in the advertising order.  A router
    with a better (lower numbered) rank will always send responding
    advertisements faster than one with a worse rank.

Ranking Identifier: An value derived from the identity of the
    advertising router, used in ranking calculations.

Ranking Score: A score calculated from the router's preference and
    Ranking Identifier.  This score is used to order the routers on
    the link and determine their Rank.

   Router-to-Router message: A new ICMPv6 message which uses the same
      options format as IPv6 Neighbour Discovery, but is only used for
      communication between routers on a local link.  It provides a
      means by which routers can advertise their configuration status
      and request that other routers do the same.

   Separation: A period after the transmission of a previous RA that the
      router must wait.  The separation time is defined by the preceding
      router.

   Token Bucket A finite sized non-negative resource counter which
      increases at a set rate while the number of resource tokens in the
      bucket is not at maximum.  When a resource is to be allocated,
      there must be a non-zero number of resource tokens in the bucket.
      As the token is allocated the resource counter decrements.

   Unicast Fast Router Advertisement A Fast Router Advertisement sent to
      the unicast source address of a Router Solicitation.  Unicast Fast
      RAs can be sent while there are tokens in the Unicast FastRA token
      bucket as defined in [6].


## 3.  Protocol Operation

   Routers wishing to provide Fast Router Advertisement need to check if
   other routers on the link are providing Fast RAs and agree on a
   relative ordering and delay before response.  This negotiation takes
   place prior to Fast RA operation, when routers are first configured,
   start or change their preferences.

   This allows all Fast Routers to send responses to Router
   Solicitations at the agreed delay, without introducing additional
   variable delays.  Delays and ordering are therefore deterministic,
   and one responding Fast Advertising Router (the Fastest) will be able
   to transmit Router Advertisements in response to solicitation with no
   delay at all.

   During transition periods where router ordering changes, router
   advertise their changed configuration to peer routers using ICMPv6
   Router-to-Router messages, defined in this document.

### 3.1  Deterministic Fast Router Advertisement Concepts

   To agree on when to send responses, Fast RA routers need to know
   which routers are Fast Routers, and must agree on their relative
   order for RS response.  In this document, the ordinal position agreed
   to by a router is its Rank.

The lowest number provides the best Rank, and the fastest responding
router has a Rank of 1.  The ranking algorithm seeks to avoid ties,
although from time to time, multiple routers will be seen to have the
same Rank.  Handling of this condition is specified in Section 6.

Upon determining the advertisement order, each router needs to choose
a delay exceeding that advertised by its better Ranked routers.  To
do this it inspects advertised values for other routers and
advertises its own Fixed Delay value exceeding this.  The Fixed Delay
is the lowest value used by the router as delay for responding to
Router Solicitations.  In this fashion, a poorly ranked router needs
only to inspect the immediately preceding routers' status messages to
guarantee that it exceeds the expected values.

At this stage, routers introduce a Separation time, which is used to
separate the Fast Router Advertisements.  A worse Ranked router must
select a delay greater than or equal to the sum of the advertised
Fixed Delay and Separation of its immediately preceding router(s).

3.2  **Router-to-Router Status Communication**

In order to accomplish Ranking and delay agreement between routers on
a link, messages need to be exchanged between FastRA routers.  These
messages contain information about the router's current configuration
status, and indicate that FastRA is in use.  This document specifies
the Router-to-Router(RtR) ICMPv6 message which allows configuration
status to be requested from other routers while advertising the
router's own status.

In negotiating with other routers on a link, trust of a router's
identity and authorization needs to be established, and mechanisms to
check these must be devised.  The Router-to-Router message is able to
use the existing message formats for Secure Neighbour Discovery, and
uses the same signatures and keys which are used in Router
Solicitations and Advertisements.

Existing protocol messages such as Router Solicitation and Router
Advertisement were explicitly designed for communication between
routers and autoconfiguring hosts.  While the options deployed in
this document may have worked interoperably in existing Neighbour
Discovery messages, existing assumptions about the roles of
particular message senders (particularly as defined in Appendix D of
[2]) would be violated in doing so.

The newly defined Router-to-Router message aims to be compatible with
future protocols requiring router negotiation and agreement, and
defines an extensible option format in the same manner as IPv6
Neighbour Discovery.

## 3.3  Deterministic Fast Router Advertisement Options

   Deterministic Fast Router Advertisement Options provide the means by
   which a router's interest in being a Fast Advertising Router is
   advertised, as well as providing an indication of the router's Rank,
   Fixed Delay and Separation.

   These options are sent in Router-to-Router Status-Request messages
   from routers which wish to learn other routers' Fast RA parameters,
   and sent in Router-to-Router Status messages responding to these
   requests.  The option may also appear in Router Solicitations and
   Advertisements when communicating between a router and a host.

   This draft principally concerns the use and operation of routers
   configuring FastRA with Deterministic Fast Router Advertisement
   Options.

## 4.  Message Formats

   This document introduces one new ICMPv6 Message, the Router-to-Router
   message (RtR).  It also defines a new option for this message, The
   Deterministic FastRA Option (DetFRAO).

## 4.1  Router to Router ICMPv6 message

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Code      |           Checksum            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Reserved                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Options ...
+-+-+-+-+-+-+-+-+-+-+-+-
```

   Source Address
                 MUST be the link-local address assigned to the
                 interface from which this message is sent.

   Destination Address
                 Typically the Source Address of an invoking
                 Router-to-Router Status-Request or the
                 all-routers multicast address.

   Hop Limit     255

ICMP Fields:

Type            TBD (Suggest 191)

Code            0  -  Status Request
                1  -  Status

Checksum        The ICMPv6 checksum.

Reserved        This field is unused.  It MUST be initialized to
                zero by the sender and MUST be ignored by the
                receiver.

Valid Options:

Advertisement Interval
                The maximum delay between unsolicited Router
                Advertisement messages.  This option and its use
                are defined in Mobile IPv6.

Deterministic Fast Router Advertisement
                The configuration status for FastRA, as defined in

[Section 4.2](#)
 of this document.

CGA             An option providing information about the router's
                cryptographically generated address, as defined in
                SEND.

Nonce           This option is provided in Status-Request messages,
                and copied into Status messages when responding to
                a particular Status-Request. It is defined in SEND.

Timestamp       An indication of the time of a Status-Request or
                Status message, as perceived at the transmitter.
                This option is aims to reduce the chance of
                messages being replayed, and is defined in SEND.

Signature       A digital signature over the message (including the
                CGA Type Tag, IPv6 Source and Destination addresses
                and the entire ICMPv6 message without Signature
                option).  This option MUST be the last option in
                the message, if present, and is defined in SEND.

Future versions of this protocol may define new option types.
Receivers MUST silently ignore any options they do not recognize
and continue processing the message.

 Mobile IPv6 is defined in [4], SEND is defined in [5].

The Router-to-Router message comes with two different codes.  A
Status-Request message asks peer routers which understand the message
to report back with their configuration for the options contained in
the message.  A Status message either responds to a Status-Request or
periodically updates its peers of the configuration.

Sending of Status-Request messages is defined in Section 5.1.

Processing of Status-Request messages is performed as described for
each received option type (unknown options being ignored).  A router
MUST respond to a Status-Request message with a Status message, even
if it contains no configuration status information.

Transmission of Status messages is defined in Section 5.2.

SEND options are ignored as regards requests for status by receiving
routers.

SEND option processing is as detailed in [5] and particularly, all
secured Router-to-Router messages MUST contain the Signature and
Timestamp options.  Status-Request messages act as if they are
solicitations for the inclusion of CGA options and Nonce Options.
CGA and Nonce Options MUST also be present in Status messages which
respond to a Status-Request.  Where the Status messages are sent
otherwise they SHOULD include the CGA Option regularly to ensure that
routers newly arrived on the link are able to verify their message.

## 4.2  Deterministic Fast Router Advertisement Option Format

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |     Rank      |    Reserved   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Fixed Delay           |   Separation  |    Rel Pref   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fields:

   Type            TBD (Suggest 13)

   Length          The length of the option (including the type and
                   length fields) in units of 8 octets.  Routers
                   compliant with this document MUST set the
                   length to 1.  If the option is received in a
                   Router-to-Router message with a length greater
                   than one the router MUST NOT read the option's
                   contents, and MUST set the IncompatibleFastRouters
                   flag on the interface until the advertising router
                   disappears or begins advertising with an option
                   length of 1.

   Rank            An integer in the range 0-255 indicating the the
                   ordinal position of the Fast Router.

   Reserved        This field MUST be set to zero and be MUST be
                   ignored by receivers.

   Fixed Delay     The minimum delay used by this router to send
                   Router Advertisements in response to Router
                   Solicitation.
                   (Units: milliseconds)

   Separation      A delay after the current router's Fixed Delay
                   that worse ranked routers wait before transmitting.
                   (Units: milliseconds)

   Rel Pref        The Relative Preference of the router seeking to
                   perform Fast Router Advertisement.  This is set
                   to the variable FastRARelPref.

  This option may appear in Router-to-Router, Router Solicitation and
  Router Advertisement messages.  Nodes receiving this option in other
  messages MUST ignore it, acting as if they didn't understand the
  option.

## 4.2.1  Rank

  The Router ranked 1 will be the fastest router, and SHOULD configure
  a Fixed Delay of 0.  No router may adopt a rank (other than
  BOOTSTRAP_RANK) until it has undertaken router querying as defined in
  Section 7.

### 4.2.2  Fixed Delay

The router determines its Fixed Delay by summing its immediately
preceding router's Fixed Delay and Separation values.

The Fastest Router SHOULD set its Fixed Delay to 0.

### 4.2.3  Separation

This value for the Fast Router's Separation from subsequent Fast
Routers exceeds the maximum additional delay over Fixed Delay
required to transmit a Fast Router Advertisement.

This delay MUST allow for computation delays in forming the RA (such
as incurred with SEND) [5].

### 4.2.4  Relative Preference

This is an integer number providing the relative preference of the
fast router for Rank determination.  It is controlled by the variable
FastRARelPref which MUST be configurable by the router's
administrator.  This value is prepended to the 24 bit Rank Identifier
in order to provide a Ranking Score, as described in Section 6.

A lower value will increase the preference of the router, and will
outrank routers configured with the default preference value of
DEF_REL_PREF.

Changes in a router's FastRA preference MAY be advertised immediately
based on its newly calculated Rank, since routers should be checking
if the Ranking Identifier associated with a particular router already
exists in the Fast Router List, and will move the existing entry to
its new location in the Fast Router List.

### 5.  Sending Router-to-Router messages

Router-to-Router messages indicate the router's current configuration
and may request a response from a peer router, with its own
configuration status.

### 5.1  Sending Router-to-Router Status-Requests

When seeking to learn about other routers' status, a router may send
Router-to-Router status Requests to its peers.

In doing so the router delays randomly for between 0 and
MAX_RTR_STATUS_REQ_DELAY, and then sends up to MAX_RTR_STATUS_REQS
requests separated by at least RTR_STATUS_REQ_INTERVAL seconds.

These messages are sent to the all-routers multicast group, and
contain the Nonce, Signature, CGA and Timestamp options (at least) if
CGA is used.

## 5.2  Sending Router-to-Router Status

Router-to-Router Status messages MAY be sent periodically to other
routers to update the peers although the router's own reachability is
readily confirmed by periodic unsolicited RA reception.

When changes in configuration occur, the router SHOULD send up to
MAX_RTR_STATUS_REQS separated by MIN_DELAY_BETWEEN_RTR_STATUS after
an initial random delay of between 0 and MAX_RTR_STATUS_DELAY.

Responses to Status-Request messages MUST be sent.

This responding Status MUST be sent after a random delay of 0 to
MAX_RTR_STATUS_DELAY.  Additionally, multicast Status Messages MUST
NOT be sent more regularly than once every
MIN_DELAY_BETWEEN_RTR_STATUS on average.

Responding Status messages MAY be sent to the unicast source address
of the Status-Request.  If MIN_DELAY_BETWEEN_RTR_STATUS has elapsed
since the last multicast Status message, the response SHOULD be
multicast to the all-routers group.

## 6.  Ranking Calculation

When receiving Router-to-Router messages containing the DetFRAO, a
router may maintain a list of Fast Routers and determines a relative
order amongst them.  Changes in the relative order trigger changes in
Router Advertisement delays, so calculations for Rank need to be done
simply, and reliably on information available in each
Router-to-Router message with a Deterministic FastRA option.

Every Router-to-Router message is sent from a unicast link-local
address uniquely owned (on the link) by the router.  Additionally,
every DetFRA Option contains a Rel Pref variable, which indicates the
configured preference of this router over others.

When receiving an Router-to-Router message containing a DetFRAO, the
Ranking Score is calculated by appending the Rank Identifier to the
Rel Pref value received in the DetFRAO.

The Rank Identifier is created by taking the final 24 bits of the
router's advertising link-local address and XOR'ing this value with
0xffffff.

As an example, using 32 bit unsigned integers, Ranking Score
computation is as follows:


```
RankID = ((ntohl(ll.s6_addr32[3]) & 0x00ffffff) ^ 0x00ffffff);
RScore = RankID | (relpref << 24);
```

A discussion of the reasoning behind this algorithm is provided in
Section 6.1.

The router with the lowest Ranking Score assumes the Rank: 1, and the
next lowest Rank: 2, etc.

In the situation where routers share the same Ranking Score and
Identifier, comparison of the routers' complete IPv6 link-local
address is made, in order to break ties.

The Ranking Identifier SHOULD be used to determine if a received
router's preference has changed, by checking if the Ranking
Identifier (as a lookup for the Source Address of the received
message) is already present in the list, and has a different Ranking
Score.  In this case, the old entry is overridden by a more recent
advertisement, and list entries consequently are re-Ranked.

Note that during ranking calculation the advertised option's Rank
field is not consulted, although it may be checked subsequently.

## 6.1  Ranking Score Calculation Reasoning

Selecting the low-order 24 bits of the IPv6 address allows selection
of fastest router in the case of interface identifier creation from
MAC-48 addresses, without reference to manufacturer's
Organizationally Unique Identifier (OUI).  Use of the XOR reverses
the order of the IPv6 address suffix so that EUI-64 based addresses
favour newer routers rather than older ones (unlike in [8] for the
case where OUIs are the same), and the relative preference overrides
all[7].

Maintaining this structure (RelPref,Suffix) allows routers to check
not only the relative ordering of a router in the list on DetFRAO
reception, but allows even Router Advertisements which do not contain
DetFRAOs to update the validity of the Fast Router's existing list
entry by matching Rank Identifiers created from the RA's source
address (if this is a unique match).

## 7.  Becoming a Fast Router

When a router wishes to be a Fast Router, it needs to check if anyone

else is acting as a Fast Router on this link.  The router begins this
bootstrap process sending Status-Request messages containing a
DetFRAO, as defined in Section 5.1.

The Deterministic FastRA option in this case MUST contain the values:


     Rank       = BOOTSTRAP_RANK
     Fixed Delay= BOOTSTRAP_DELAY
     Separation = FastRASep
     Rel Pref   = FastRARelPref

Receivers will see this option and recognise that the requester is a
bootstrapping router.  As defined in Section 8.4, the routers MUST
send a Status message responding to the request containing the DetFRA
option.  This informs the requester of their own identity, Rank and
delays.

While collecting information about other routers, the bootstrapping
router MUST send Router-to-Router messages with the DetFRA option.
It MUST delay when sending responses to Router Solicitations by 0 to
MAX_RA_DELAY_TIME, and ensure that MIN_DELAY_BETWEEN_RAS separates
multicast advertisements.

After collecting this information, the new Fast Router calculates its
Rank and begins advertising as described in Section 9.1.

## 8.  Receiving DetFRAO in ICMPv6 Router-to-Router

When receiving Router-to-Router messages with the DetFRAO option, the
router determines whether the transmitting router has been seen
before, and whether the transmitted Rank, Fixed Delay or Separation
have changed.  If either the router is previously unseen or the
ranking or delay parameters have changed, the entry is inserted into
the list at the position indicated by the router's Ranking Scores.

If the delay or rank of the receiving router have changed, it
advertises its changed configuration as indicated in Section 9.1.

It SHOULD also send a unicast Status message to the transmitter of a
Status-Request message if change occurred due to the option in that
request.

## 8.1  Dealing with Duplicate List Entries

Where Router-to-Router messages are received with a DetFRA Option
indicating the the same rank as another preceding entry, then the
receiving router MUST configure its Rank to be the number of elements

preceding it in the Fast Routers List plus one, and the router's own
fixed delay MUST be configured to the maximum immediately preceding
routers' fixed delays plus both of the other routers' received
Separation values.

This ensures the router is will not then collide with a router which
subsequently increases its Rank.

When this change occurs, advertisement follows the procedures in
Section 9.1.

## 8.2  Receiving Bootstrap Deterministic FastRA Options

Deterministic FastRA routers or bootstrapping routers may receive
Router-to-Router messages containing a DetFRAO from a bootstrapping
router.

Routers SHOULD add such routers into their Fast Router List, in
anticipation of the router's arrival as a fully functioning Fast
Router.

Calculations for the Rank and Fixed delay of the bootstrapping Router
MUST NOT be made based on the values in the received Option, but on
the Ranking Score generated as described in Section 6.  The Fixed
Delay calculated for the bootstrap router should be the sum of the
preceding router's Fixed Delay and Separation.

## 8.3  Cleaning up old entries

If a Fast Router fails to receive multiple expected Router
Advertisement packets from a peer router, it SHOULD check if the peer
router is dead using either router or neighbour discovery .  Such
mechanisms may be invoked upon non-reception of advertisements in
multiple retransmission intervals as advertised by the peer router,
or non-response to previous Router-to-Router Status-Request [4].

If the peer is dead, the local router removes its entry from the
list, and re-advertises its own preference and distance as defined in
Section 9.1, if any change has occurred.

If one of a router's preceding routers reduces their Rank, so that it
conflicts with another router in the list, a router MAY send a
Router-to-Router Status-Request message containing DetFRAO after a
random delay between 0 and MAX_RTR_STATUS_REQ_DELAY, to establish
whether routers are still reachable.

## 8.4  Responding to Status-Requests with DetFRAO

   A router MUST send a Deterministic FastRA option to a router which
   sends a Router-to-Router Status-Request to it, if the router is
   trusted.  Delays to Status message are described in Section 5.2.

## 9.  Sending DetFRAOs in ICMPv6 Router-to-Router


## 9.1  Sending RAs on Rank or Delay Change

   In the case that a router's Rank, Fixed Delay or Separation change,
   it MUST transmit a Router-to-Router Status message after a delay of
   between 0 and MAX_RTR_STATUS_DELAY seconds and then
   MAX_INITIAL_RTR_STATUS-1 messages each separated by
   MIN_DELAY_BETWEEN_RTR_STATUS seconds (as described in Section 5.2.

   If subsequent changes occur within this interval, it extends such
   that three multicast Router-to-Router Status messages are sent with
   the new configuration.  This allows all peer routers to be updated in
   a configuration interval of less than 12.5 seconds, if one set of
   changes occurs.

## 9.2  Sending Advertisement Intervals

   When a router advertises Deterministic Fast RA Options in
   Router-to-Router messages, it MAY also indicate the frequency of its
   periodic Router Advertisements using Advertisement Interval Options
   in the message if there is room.

   Alternatively, a router may advertise the interval in its Router
   Advertisement messages as defined in [4].

   This option allows receiving routers to know how often to expect
   these Router Advertisements, so that they can check that the
   advertising router is active if expected packets are not received (as
   in Section 8.3).

   Routers MAY send DetFRAOs occasionally in their periodic unsolicited
   Router Advertisements, in order to show hosts their FastRA
   configuration.

## 10.  Sending Fast Router Advertisements

   Fast Router Advertisements are sent in response to Router
   Solicitations.  Where Deterministic Fast Router Advertisement Options
   have been exchanged, and the routers know their fixed delays, Router
   Advertisements are transmitted to the solicitor after delaying for

the Fixed Delay.

The number of FastRAs which may be sent at any time are determined by trading off the reasonable arrival rate of Router Solicitations, and the bandwidth and delay consumption caused by having all of these packets transmitted successively[6].

Determining good values for these outstanding FastRA bucket sizes is not well described and may require further work.  The values defined in this document are approximations thought to be relatively harmless based on other protocol defaults, at the time of writing.

### 10.1  Sending Unicast Fast RAs

The same resource DoS protection mechanisms for unicast FastRAs used in the FastRA Draft are used in this document.  Particularly, the maximum token bucket size is limited to MaxFastRAs, which defaults to MAXFASTRAS (10) [6].

The FastRA draft places up to MaxFastRAs tokens into the bucket each multicast Router Advertisement interval.

In order to provide more flexible replenishment of FastRA resources, a router MAY place unicast FastRA tokens into the bucket at a rate of one every FastRARefreshIval ms, where this defaults to FASTRAREFRESHIVAL.

### 10.2  Sending Multicast Fast RAs

Multicast Fast RAs are not supported in the original FastRA draft [6].  It does make sense for routers to provide fast multicast responses to Router Solicitations, where such solicitations do not create sufficient neighbour cache state to allow immediate unicast response.

Also, if a router has multiple Unicast FastRAs delayed before transmission, it may be possible to send a multicast FastRA instead at the earliest of the delay times, in order to reduce the number of responses required.

Multicast Fast RA transmission is managed separately to unicast transmission, and has a token bucket with a size of MaxMCFastRAs which defaults to MAXMCFASTRAS.

Tokens are placed into this bucket at a rate of one every MIN_DELAY_BETWEEN_RAS.

**11**.  **Interaction with Other Routers**

   Not all routers will understand Deterministic FastRA options or want
   to be in a Fast Router List.  This section describes interactions
   between Fast Routers and other routers.

**11.1**  **Presence of Legacy Routers**

   Deterministic Fast Routers ignore the presence of Legacy Routers when
   building their Fast Router List.  Fast Routers rely upon these
   routers undertaking random delays according to IPv6 Neighbour
   Discovery[2].

**11.2**  **Ceasing to be a Fast Router**

   A router which no longer wishes to undertake FastRA may stop making
   fast responses at any time, but SHOULD delay by a random value
   between 0 and MAX_RTR_STATUS_DELAY, before sending
   MAX_INITIAL_RTR_STATUS successive multicast Router-to-Router Status
   messages.  These messages MUST contain the DetFRA option with Rank
   set to NOT_FAST_RTR_RANK and an advertised Fixed Delay of
   NOT_FAST_RTR_DELAY.  These multicast Router Advertisements SHOULD be
   sent once every MIN_DELAY_BETWEEN_RTR_STATUS to the all-routers
   group.

   While a router advertises its Fixed Delay as NOT_FAST_RTR_DELAY, it
   in fact reverts to the procedures defined in IPv6 Neighbour Discovery
   [2].

   Routers receiving this option in a Router-to-Router message SHOULD
   remove the router from the Fast Routers List, and recalculate
   subsequent Ranks and delays of routers remaining in the list.

   This may lead to peer routers' re-advertisement of new Ranks and
   delays as described in Section 9.1.

**11.3**  **Presence of Non Fast Routers**

   While a router may be able to understand and process DetFRAOs, it may
   not wish to be a Fast Router.  Routers which have completed
   advertising their leaving of the Fast Routers List fall into this
   category.

   These routers SHOULD act like legacy routers, and ignore
   Deterministic FastRA options as if they didn't understand them.

**11.4**  **Presence of Incompatible Fast Routers**

   When routers wishing to undertake FastRA exist on the link but are
   not trusted for inclusion in the Fast Routers List, two distinct sets
   of routers may appear.

   Each set may not trust another, and may instead have its own router
   at each Rank.  In this case, the IncompatibleFastRouters flag SHOULD
   be set on the interface until the untrusted routers become trusted,
   or cease being Fast Routers.

   Each Fast Router which has the IncompatibleFastRouters flag MUST
   attempt to inform its administrator about the misconfiguration.

**12**.  **Host interaction with DetFRAOs**

   While the principle use of Deterministic FastRA options is for router
   to router configuration, the options may be used to pass information
   to hosts.

**12.1**  **Host Transmission of DetFRAOs**

   A host may transmit a Deterministic FastRA option in a Router
   Solicitation.  This option MUST be sent with a Rank of
   NOT_FAST_RTR_RANK and a Fixed Delay of NOT_FAST_RTR_DELAY.

   This option in a solicitation requests that the responding Router
   Advertisement contains a Deterministic FastRA option.

**12.2**  **Reception of DetFRAOs in Router Solicitations**

   Routers receiving a DetFRAO option in a Router Solicitation sends a
   Router Advertisement responding to the solicitation if it is able to
   do so.  In responding to the solicitation with this option, the
   Router Advertisement MAY contain the router's own configuration in a
   DetFRAO.

**12.3**  **Transmission of DetFRAOs in Router Advertisements**

   Routers MAY inform hosts of their status by including their
   Router-to-Router status in some unsolicited Router Advertisements.
   If a router does this, it SHOULD inform them with updated options
   after configuration status change.

**12.4**  **Host Reception of DetFRAOs**

   If a host which configures a router receives a DetFRAO from this
   router in a Router Advertisement, it can determine the routers' Ranks

and delays.

If when receiving a Router Advertisement in response to its
solicitation it receives a DetFRAO with a Rank which matches an
existing configured router, it may suspect change has occurred.

Where no prefixes exist in common with the previously received
advertisements, reception of a FastRA from a router within the
reception interval defined by another router either implies a new
router joining the link, or a link change.

Since new routers joining a Fast Router Advertisement set are
unlikely to occur often, a host MAY assume that the new router is on
a new link, and begin configuration operations.

Where a single router has joined a link, the next best Fast Router
will then be the previously configured router, if the host remains on
the same link.  Therefore, a host MAY delay until after the sum of
the old and newly received routers' Separation have elapsed before
concluding that link change has occurred.  This additional cost is
likely to be less than that incurred with Legacy Router
Advertisements, but provides slightly more safety than the previous
heuristic.

## 13.  Configuration Parameters

The following parameters are defined in this document:

    FastRARelPref          A parameter which controls the
                           ranking of Fast Routers.  It sets
                           the advertised Rel Pref field in
                           the DetFRAO. Setting this value lower
                           betters the preference of the router.

                           Minimum:   0
                           Maximum:   255
                           Default:   DEF_REL_PREF

    FastRASep              A parameter controlling the delay between
                           scheduling of Fast Router Advertisements
                           on adjacent routers in the Fast Routers
                           List.
                           (Units: milliseconds)

                           Minimum:   1
                           Maximum:   255
                           Default:   DEF_SEP

    MaxFastRAs             The maximum bucket size for Unicast
                           FastRAs
  [6]
  .

                           Minimum:   0 (not Fast RA)
                           Default:   MAXFASTRAS

    MaxMCFastRAs           The maximum bucket size for Multicast
                           FastRAs.

                           Minimum:   0 (no Multicast Fast RA)
                           Default:   MAXMCFASTRAS


**14. Protocol Constants**

```
         BOOTSTRAP_DELAY                    500ms
         BOOTSTRAP_RANK                     254
         DEF_SEP                            50ms
         DEF_REL_PREF                       127
         MAXMCFASTRAS                       5
         MAX_INITIAL_RTR_STATUS             3
         MAX_RTR_STATUS_REQ_DELAY           1000ms
         MAX_RTR_STATUS_REQS                3
         MAX_RTR_STATUS_DELAY               500ms
         MIN_DELAY_BETWEEN_RTR_STATUS       3 seconds
         NOT_FAST_RTR_DELAY                 500ms
         NOT_FAST_RTR_RANK                  255
         RTR_STATUS_REQ_INTERVAL            4 seconds
         UCASTFASTRAREFRESHIVAL             400ms
```

## 15.  IANA Considerations

   The new ICMPv6 message type - Router to Router (with two codes) and a
   new ICMPv6 'Deterministic Fast Router Advertisement Option' are
   defined in this document.

   The Router-to-Router message is suggested to be an Informational
   ICMPv6 message and is defined in Section 4.1.

   (DetFRAO) is defined in Section 4.2 of this document.  It is
   suggested that the option number 13 is used for the Type of this
   option.

## 16.  Security Considerations

   The Router-to-Router message's use of the Neighbour Discovery option
   format allows SEND options to be used to check the authenticity of
   the messages sent from the peer router.

   The authorization of a node to be a router is described by a
   delegation chain advertised in a succession of Delegation Chain
   Advertisement messages.  When using SEND, routers MUST check that the
   router from which they receive a DetFRAO is an authorized router from
   that link, and that the router trusts the delegation service used to
   sign this authorization [5].

   Where the Router-to-Router message is not trusted, but contains a
   Deterministic FastRA Option, the router MUST NOT include the router
   in its Fast Router List, but SHOULD set the IncompatibleFastRouters
   flag on that interface.  This will turn attempt to inform the
   administrator of the configuration problem.

   Where disjoint sets of routers each undertake FastRA (but don't trust
   each other), they can choose the same delay timers for sending
   FastRA.  In the worst case this means that every FastRA sent will
   collide with another RA.  Administrative action is currently required
   to fix this issue, but further work may establish if automated
   robustness to this issue is desirable.

## 17.  Acknowledgments

   This work is based on and expands the FastRA internet-draft [6].

## 18.  References

### 18.1  Normative References

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         Advertisement", draft-mkhalil-ipv6-fastra-02 (work in progress),
         October 2002.

### 18.2  Informative References

   [7]   Hinden, R. and S. Deering, "Internet Protocol Version 6 (IPv6)
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## Appendix A.  State Diagram

     Below is a state diagram for Fast Router Advertisement.

```
    Legend:
    -------
    FD     : Fixed Delay
    TmrSet : Set Timer value(milliseconds)
    DetFRAO: Deterministic Fast RA Option
    RSResp : Response to Router Solicitation
    S      : Router-to-Router Status
    SR:    : Router-to-Router Status-Request
    TmrExp : A timer expiry
    TmrExp4: Fourth Timer Expiry(resets counter)


          TmrExp,SR /-\ /-\ Recv:                 TmrExp,S /-\
          TmrSet:4K | | | | DetFRAO               TmrSet:3K| |
   *                 \V  \V                                 \V
   /----\            /-----\TmrExp4 /---------\       /-------\
   |Not |-------------->|Boot |------->| Changed |-------->|Adv     |
   |Fast|TmrSet:        |Strap|        | RtrSet  |Sort List|Change |
   \----/[0,1000]       \-----/      7\---------/Calc:FD  \-------/
       ^           RSResp ^\          /        ^ ^  TmrSet:        ^\  \
       |           Delay: | |        /         | |  [0,500]        | |  \
       |           [0,500] \-/      /   Option| |                 \-/   \
       |                          |   Change| |         RSResp        \
       |                    Pref \   or Add| |         Delay: FD     |
       |    TmrExp,RA /-\      Change\        | |List                  /
       \    TmrSet:3K | |            \        | |Entry                /
   Stop \           \V             \       | |Timeout           /
   FastRA\       /------\            /-------------\            /
       \------|Adv   |            |   Steady    |<------------/
              |Leave |<-------------|   State     |   TmrExp4
              \------/Leave List    \-------------/
        RSResp  ^\    TmrSet:[0,500]      ^\  RSResp
        Delay:  | |                       | | Delay: FD
        [0,500] \-/                       \-/
```
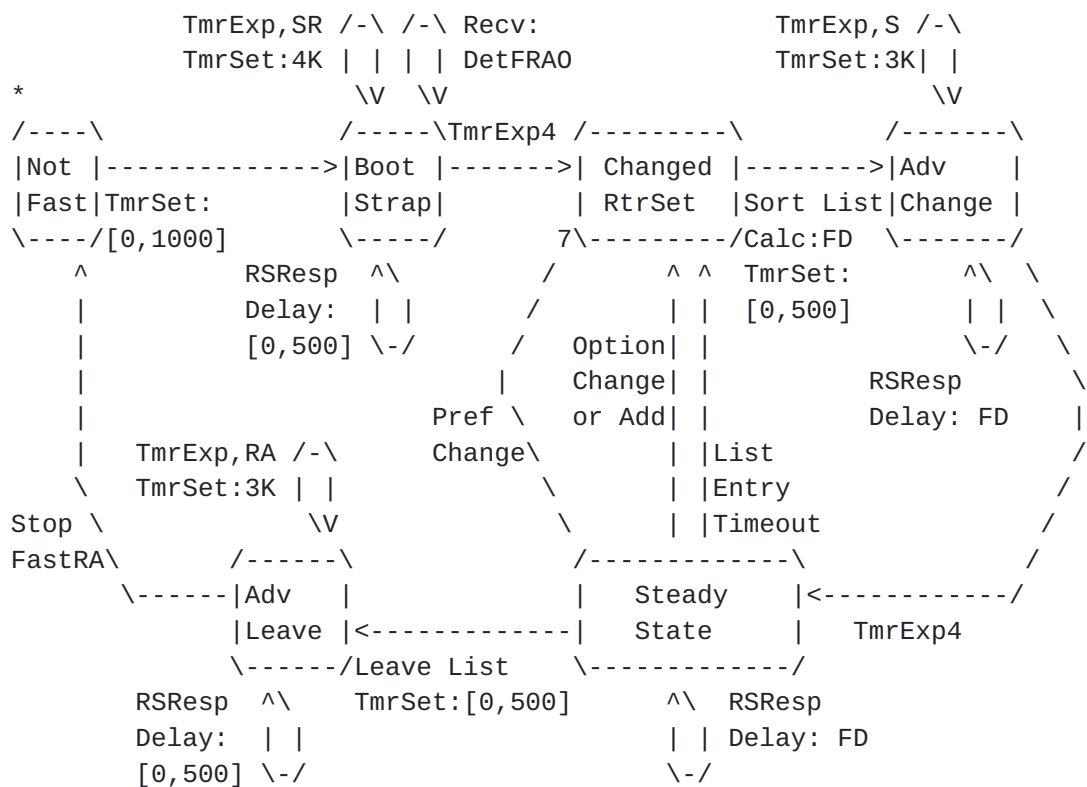
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