

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: November 09, 2013

K. Ogawa  
NTT Corporation  
W. M. Wang  
Zhejiang Gongshang University  
E. Haleplidis  
University of Patras  
J. Hadi Salim  
Mojatatu Networks  
May 08, 2013

**ForCES Intra-NE High Availability**  
**draft-ietf-forces-ceha-07**

**Abstract**

This document discusses Control Element High Availability within a ForCES Network Element.

**Status of This Memo**

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on November 09, 2013.

**Copyright Notice**

Copyright (c) 2013 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in [Section 4.e](#) of

the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

<a href="#">1.</a>	<a href="#">Definitions . . . . .</a>	<a href="#">2</a>
<a href="#">2.</a>	<a href="#">Introduction . . . . .</a>	<a href="#">3</a>
<a href="#">2.1.</a>	<a href="#">Document Scope . . . . .</a>	<a href="#">5</a>
<a href="#">2.2.</a>	<a href="#">Quantifying Problem Scope . . . . .</a>	<a href="#">5</a>
<a href="#">3.</a>	<a href="#">RFC5810 CE HA Framework . . . . .</a>	<a href="#">6</a>
<a href="#">3.1.</a>	<a href="#">RFC 5810 CE HA Support . . . . .</a>	<a href="#">6</a>
<a href="#">3.1.1.</a>	<a href="#">Cold Standby Interaction with ForCES Protocol . . . . .</a>	<a href="#">7</a>
<a href="#">3.1.2.</a>	<a href="#">Responsibilities for HA . . . . .</a>	<a href="#">9</a>
<a href="#">4.</a>	<a href="#">CE HA Hot Standby . . . . .</a>	<a href="#">10</a>
<a href="#">4.1.</a>	<a href="#">Changes to the FEPO model . . . . .</a>	<a href="#">10</a>
<a href="#">4.2.</a>	<a href="#">FEPO processing . . . . .</a>	<a href="#">12</a>
<a href="#">5.</a>	<a href="#">IANA Considerations . . . . .</a>	<a href="#">15</a>
<a href="#">6.</a>	<a href="#">Security Considerations . . . . .</a>	<a href="#">15</a>
<a href="#">7.</a>	<a href="#">References . . . . .</a>	<a href="#">16</a>
<a href="#">7.1.</a>	<a href="#">Normative References . . . . .</a>	<a href="#">16</a>
<a href="#">7.2.</a>	<a href="#">Informative References . . . . .</a>	<a href="#">16</a>
<a href="#">Appendix A.</a>	<a href="#">New FEPO version . . . . .</a>	<a href="#">16</a>
	<a href="#">Authors' Addresses . . . . .</a>	<a href="#">25</a>

## 1. Definitions

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](#).

The following definitions are taken from [[RFC3654](#)] and [[RFC3746](#)]:

- o Logical Functional Block (LFB) -- A template that represents a fine-grained, logically separate aspects of FE processing.
- o ForCES Protocol -- The protocol used at the Fp reference point in the ForCES Framework in [[RFC3746](#)].
- o ForCES Protocol Layer (ForCES PL) -- A layer in the ForCES architecture that embodies the ForCES protocol and the state transfer mechanisms as defined in [[RFC5810](#)].
- o ForCES Protocol Transport Mapping Layer (ForCES TML) -- A layer in ForCES protocol architecture that specifically addresses the protocol message transportation issues, such as how the protocol messages are mapped to different transport media (like SCTP, IP, TCP, UDP, ATM, Ethernet, etc), and how to achieve and implement reliability, security, etc.



- o Forwarding Element (FE) - A logical entity that implements the ForCES Protocol. FEs use the underlying hardware to provide per-packet processing and handling as directed by a CE via the ForCES Protocol.
- o Control Element (CE) - A logical entity that implements the ForCES Protocol and uses it to instruct one or more FEs on how to process packets. CEs handle functionality such as the execution of control and signaling protocols.
- o ForCES Network Element (NE) - An entity composed of one or more CEs and one or more FEs. An NE usually hides its internal organization from external entities and represents a single point of management to entities outside the NE.
- o FE Manager (FEM) - A logical entity that operates in the pre-association phase and is responsible for determining to which CE(s) an FE should communicate. This process is called CE discovery and may involve the FE manager learning the capabilities of available CEs.
- o CE Manager - A logical entity that operates in the pre-association phase and is responsible for determining to which FE(s) a CE should communicate. This process is called FE discovery and may involve the CE manager learning the capabilities of available FEs.

## **2. Introduction**

Figure 1 illustrates a ForCES NE controlled by a set of redundant CEs with CE1 being active and CE2 and CEN being a backup.



The ForCES architecture allows FEs to be aware of multiple CEs but enforces that only one CE be the master controller. This is known in the industry as 1+N redundancy. The master CE controls the FEs via the ForCES protocol operating in the Fp interface. If the master CE becomes faulty, a backup CE takes over and NE operation continues. By definition, the current documented setup is known as cold-standby. The set of CEs controlling an FE is static and is passed to the FE by the FE Manager (FEM) via the Ff interface and to each CE by the CE Manager (CEM) in the Fc interface during the pre-association phase.



From an FE perspective, the knobs of control for a CE set are defined by the FEPO LFB in [\[RFC5810\]](#), [Appendix B](#). In [Section 3.1](#) of this document we discuss further details of these knobs.

### **[2.1.](#) Document Scope**

It is assumed that the reader is aware of the ForCES architecture to make sense of the changes being described in this document. This document provides background information to set the context of the discussion in [Section 4](#).

At the time this document is being written, the Fr interface is out of scope for the ForCES architecture. However, it is expected that organizations implementing a set of CEs will need to have the CEs communicate to each other via the Fr interface in order to achieve the synchronization necessary for controlling the FEs.

The problem scope addressed by this document falls into 2 areas:

1. To describe with more clarity (than [\[RFC5810\]](#)) how current cold-standby approach operates within the NE cluster.
2. To describe how to evolve the [\[RFC5810\]](#) cold-standby setup to a hot-standby redundancy setup to improve the failover time and NE availability.

### **[2.2.](#) Quantifying Problem Scope**

The NE recovery and availability is dependent on several time-sensitive metrics:

1. How fast the CE plane failure is detected by the FE.
2. How fast a backup CE becomes operational.
3. How fast the FEs associate with the new master CE.
4. How fast the FEs recover their state and become operational.

The design intent of the current [\[RFC5810\]](#) as well as this document to meet the above goals are driven by desire for simplicity.

To quantify the above criteria with the current prescribed ForCES CE setup in [\[RFC5810\]](#):

1. How fast the FE side detects a CE failure is left undefined. To illustrate an extreme scenario, we could have a human operator acting as the monitoring entity to detect faulty CEs. How fast





such detection happens could be in the range of seconds to days. A more active monitor on the Fr interface could improve this detection.

2. How fast the backup CE becomes operational is also currently out of scope. In the current setup, a backup CE need not be operational at all (for example, to save power) and therefore it is feasible for a monitoring entity to boot up a backup CE after it detects the failure of the master CE. In this document [Section 4](#) we suggest that at least one backup CE be online so as to improve this metric.
3. How fast an FE associates with new master CE is also currently undefined. The cost of an FE connecting and associating adds to the recovery overhead. As mentioned above we suggest having at least one backup CE online. In [Section 4](#) we propose to zero out the connection and association cost on failover by having each FE associate with all online backup CEs after associating to an active/master CE. Note that if an FE pre-associates with at least one backup CE, then the system will be technically operating in hot-standby mode.
4. And last: How fast an FE recovers its state depends on how much NE state exists. By ForCES current definition, the new master CE assumes zero state on the FE and starts from scratch to update the FE. So the larger the state, the longer the recovery.

### 3. [RFC5810](#) CE HA Framework

To achieve CE High Availability (HA), FEs and CEs MUST inter-operate per [[RFC5810](#)] definition which is repeated for contextual reasons in [Section 3.1](#). It should be noted that in this default setup, which MUST be implemented by CEs and FEs requiring HA, the Fr plane is out of scope (and if available is proprietary to an implementation).

#### 3.1. [RFC 5810](#) CE HA Support

As mentioned earlier, although there can be multiple redundant CEs, only one CE actively controls FEs in a ForCES NE. In practice there may be only one backup CE. At any moment in time, only one master CE can control an FE. In addition, the FE connects and associates to only the master CE. The FE and the CE are aware of the primary and one or more secondary CEs. This information (primary, secondary CEs) is configured on the FE and the CE during pre-association by the FEM and the CEM respectively.



Figure 2 below illustrates the Forces message sequences that the FE uses to recover the connection in current defined cold-standby scheme.

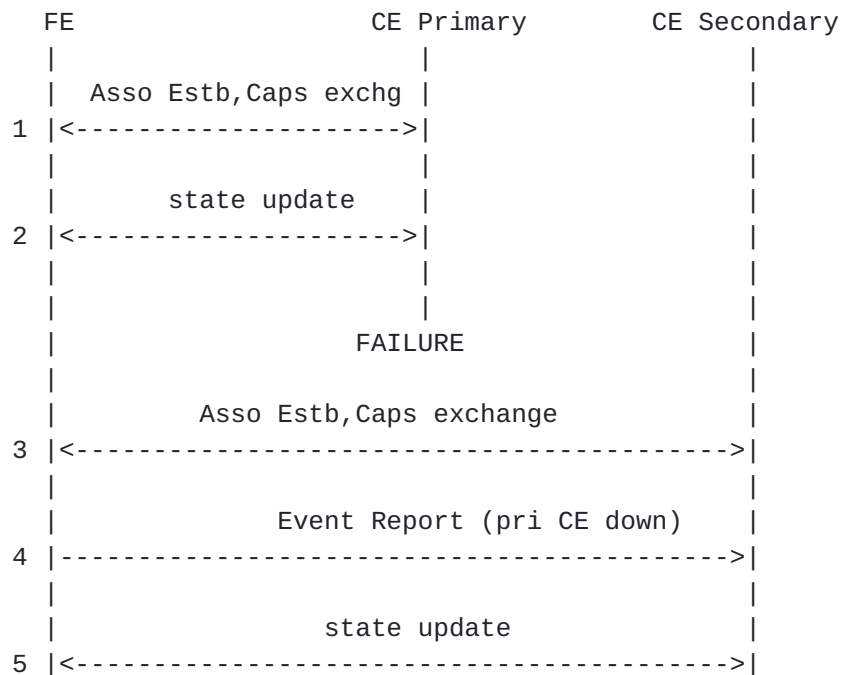


Figure 2: CE Failover for Cold Standby

### 3.1.1. Cold Standby Interaction with ForCES Protocol

HA parameterization in an FE is driven by configuring the FE Protocol Object (FEPO) LFB.

The FEPO CEID component identifies the current master CE and the component table BackupCEs identifies the configured backup CEs. The FEPO FE Heartbeat Interval, CE Heartbeat Dead Interval, and CE Heartbeat policy help in detecting connectivity problems between an FE and CE. The CE Failover policy defines how the FE should react on a detected failure. The FEObject FEState component [RFC5812] defines the operational forwarding status and control. The CE can turn off the FE's forwarding operations by setting the FEState to AdminDisable and can turn it on by setting it to OperEnable. Note: [\[RFC5812\] section 5.1](#) has an erratta which describes the FEState as read-only when it should be read-write.

Figure 3 illustrates the defined state machine that facilitates the recovery of connection state.



There are several events that trigger mastership changes: The master CE may issue a mastership change (by changing the CEID value), or teardown an existing association; and last, connectivity may be lost between the CE and FE.



When communication fails between the FE and CE (which can be caused by either the CE or link failure but not FE related), either the TML on the FE will trigger the FE PL regarding this failure or it will be detected using the HB messages between FEs and CEs. The communication failure, regardless of how it is detected, MUST be considered as a loss of association between the CE and corresponding FE.

If the FE's FEPO CE Failover Policy is configured to mode 0 (the default), it will immediately transition to the pre-association phase. This means that if association is later re-established with a CE, all FE state will need to be re-created.

If the FE's FEPO CE Failover Policy is configured to mode 1, it indicates that the FE will run in HA restart recovery. In such a case, the FE transitions to the Not Associated state and the CEFTI timer [[RFC5810](#)] is started. The FE MAY continue to forward packets during this state. The FE recycles through any configured backup CEs in a round-robin fashion. It first adds its primary CE to the bottom of table BackupCEs and sets its CEID component to be the first secondary retrieved from table BackupCEs. The FE then attempts to associate with the CE designated as the new primary CE. If it fails to re-associate with any CE and the CEFTI expires, the FE then transitions to the pre-association state and FE will operationally bring down its forwarding path (and set the [[RFC5812](#)] FEObject FEState component to OperDisable).

If the FE, while in the not associated state, manages to reconnect to a new primary CE before CEFTI expires it transitions to the Associated state. Once re-associated, the CE may try to synchronize any state that the FE may have lost during disconnection. How the CE re-synchronizes such state is out of scope for the current ForCES architecture but would typically constitute the issuing of new configs and queries.

An explicit message (a Config message setting Primary CE component in ForCES Protocol object) from the primary CE, can also be used to change the Primary CE for an FE during normal protocol operation. In this case, the FE transitions to the Not Associated State and attempts to Associate with the new CE.

### **3.1.2. Responsibilities for HA**

TML Level:

1. The TML controls logical connection availability and failover.
2. The TML also controls peer HA management.





At this level, control of all lower layers, for example transport level (such as IP addresses, MAC addresses etc) and associated links going down are the role of the TML.

PL Level:

All other functionality, including configuring the HA behavior during setup, the CE IDs used to identify primary and secondary CEs, protocol messages used to report CE failure (Event Report), Heartbeat messages used to detect association failure, messages to change the primary CE (Config), and other HA related operations described in [Section 3.1](#), are the PL's responsibility.

To put the two together, if a path to a primary CE is down, the TML would help recover from a failure by switching over to a backup path, if one is available. If the CE is totally unreachable then the PL would be informed and it would take the appropriate actions described before.

#### **4. CE HA Hot Standby**

In this section we describe small extensions to the existing scheme to enable hot standby HA. To achieve hot standby HA, we target to improve the specific goals defined in [Section 2.2](#), namely:

- o How fast a backup CE becomes operational.
- o How fast the FEs associate with the new master CE.

As described in [Section 3.1](#), in the pre-association phase the FEM configures the FE to make it aware of all the CEs in the NE. The FEM MUST configure the FE to make it aware which CE is the master and MAY specify any backup CE(s).

##### **[4.1. Changes to the FEPO model](#)**

In order for the above to be achievable there is a need to make a few changes in the FEPO model. [Appendix A](#) contains the xml definition of the new version 1.1 of the FEPO LFB.

Changes from the version 1 of FEPO are:

##### **1. Added four new datatypes:**

1. CESTatusType an unsigned char to specify status of a connection with a CE. Special values are:
  - + 0 (Disconnected) represents that no connection attempt has been made with the CE yet



- + 1 (Connected) represents that the FE connection with the CE at the TML has completed successfully
  - + 2 (Associated) represents that the FE has successfully associated with the CE
  - + 3 (IsMaster) represents that the FE has associated with the CE and is the master of the FE
  - + 4 (LostConnection) represents that the FE was associated with the CE at one point but lost the connection
  - + 5 (Unreachable) represents the FE deems this CE unreachable. i.e the FE has tried over a period to connect to it but has failed.
2. HAModeValues an unsigned char to specify selected HA mode. Special values are:
- + 0 (No HA Mode) represents that the FE is not running in HA mode
  - + 1 (HA Mode - Cold Standby) represents that the FE is in HA mode cold Standby
  - + and 2 (HA Mode - Hot Standby) represents that the FE is in HA mode hot Standby
3. Statistics, a complex structure, representing the communication statistics between the FE and CE. The components are:
- + RecvPackets representing the packet count received from the CE
  - + RecvBytes representing the byte count received from the CE
  - + RecvErrPackets representing the erroneous packets received from the CE. This component logs badly formatted packets as well as good packets sent to the FE by the CE to set components whilst that CE is not the master. Erroneous packets are dropped(i.e not responded to).
  - + RecvErrBytes representing the RecvErrPackets byte count received from the CE
  - + TxmitPackets representing the packet count transmitted to the CE



- + TxmitErrPackets representing the error packet count transmitted to the CE. Typically these would be failures due to communication.
  - + TxmitBytes representing the byte count transmitted to the CE
  - + TxmitErrBytes representing the byte count of errors from transmit to the CE
4. AllCEType, a complex structure constituting the CE ID, Statistics and CEStatusType to reflect connection information for one CE. Used in the AllCEs component array.
2. Appended two new components:
    1. Read-only AllCEs to hold status for all CEs. AllCEs is an Array of the AllCEType.
    2. Read-write HAMode of type HAModeValues to carry the HA mode used by the FE.
  3. Added one additional Event, PrimaryCEChanged, reporting the new master CEID when there is a mastership change.

Since no component from the FEPO v1 has been changed FEPO v1.1 retains backwards compatibility with CEs that know only version 1.0. These CEs however cannot make use of the HA options that the new FEPO provides.

#### **4.2. FEPO processing**

The FE's FEPO LFB version 1.1 AllCEs table contains all the CEIDs that the FE may connect and associate with. The ordering of the CE IDs in this table defines the priority order in which an FE will connect to the CEs. This table is provisioned initially from the configuration plane (FEM). In the pre-association phase, the first CE (lowest table index) in the AllCEs table MUST be the first CE that the FE will attempt to connect and associate with. If the FE fails to connect and associate with the first listed CE, it will attempt to connect to the second CE and so forth, and cycles back to the beginning of the list until there is a successful association. The FE MUST associate with at least one CE. Upon a successful association, the FEPO's CEID component identifies the current associated master CE.

While it would be much simpler to have the FE not respond to any messages from a CE other than the master, in practise it has been



```

graph TD
    subgraph "FE tries to associate"
        direction TB
        A1["(CE changes master || CE issues Teardown || Lost association) && CE failover policy = 0"]
        A2["Pre-Association in progress")"]
        A3["CE Association Response"]
        A4["FE issue CEPrimaryDown"]
        A5["FE issue PrimaryCEChanged"]
        A6["V"]
    end

    subgraph "CEFTI timer expires"
        direction TB
        B1["CEFTI timer expires"]
        B2["^"]
        B3["^"]
        B4["|"]
    end

    A1 --> A2
    A2 --> A3
    A3 --> A4
    A4 --> A5
    A5 --> A6

    A3 --> B1
    A4 --> B2
    A5 --> B3
    A6 --> B4

    subgraph "CEFTI timer expires"
        direction TB
        C1["(CE changes master || CE issues Teardown || Lost association) && CE Failover Policy = 1"]
        C2["May find first associated CE or retry associating"]
        C3["Start CEFTI timer"]
        C4["Forwarding")"]
        C5["Found associated CE or newly associated CE"]
        C6["V"]
        C7["Cancel CEFTI Timer")"]
    end

    C1 --> C2
    C2 --> C3
    C3 --> C4
    C4 --> C5
    C5 --> C6
    C6 --> C7

    C1 --> C5
    C2 --> C5
    C3 --> C5
    C4 --> C5
    C5 --> C5
    C6 --> C5
    C7 --> C5

```





FE issue CEPrimaryDown event  
 FE issue PrimaryCEChanged event

Figure 4: FE State Machine considering HA

Once the FE has associated with a master CE it moves to the post-association phase (Associated state). It is assumed that the master CE will communicate with other CEs within the NE for the purpose of synchronization via the CE-CE interface. The CE-CE interface is out of scope for this document. An election result amongst CEs may result in desire to change mastership to a different associated CE; at which point current assumed master CE will instruct the FE to use a different master CE.

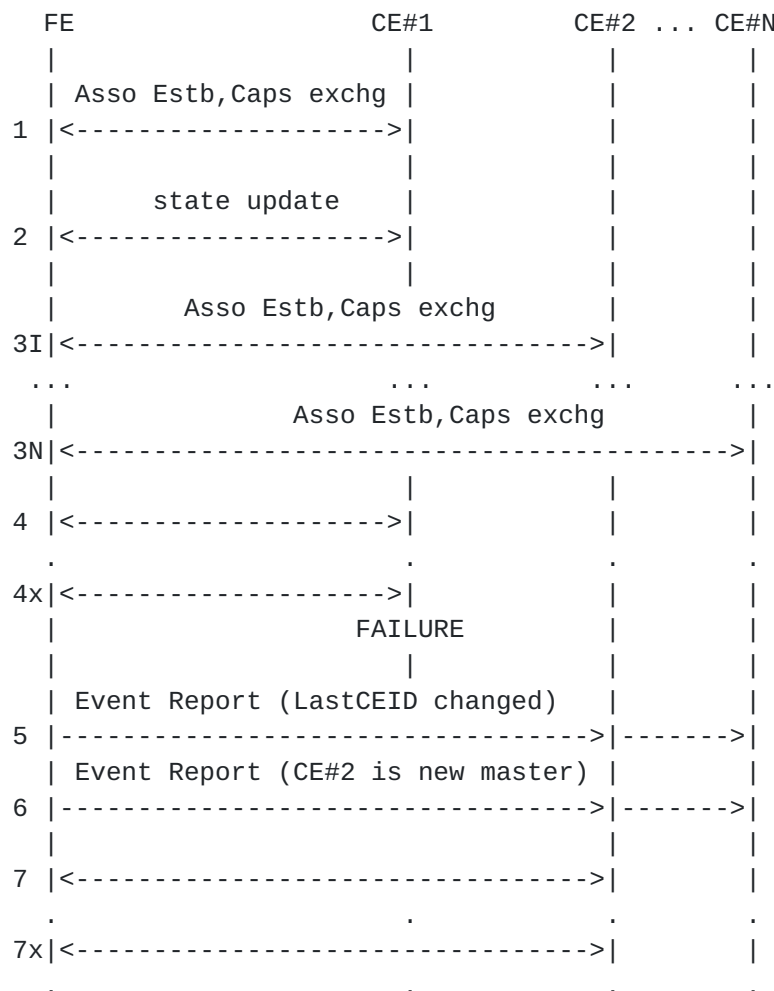


Figure 5: CE Failover for Hot Standby

While in the post-association phase, if the CE Failover Policy is set to 1 and HAMode set to 2 (HotStandby) then the FE, after successfully associating with the master CE, MUST attempt to connect and associate



with all the CEs that it is aware of. Figure 5 steps #1 and #2 illustrates the FE associating with CE#1 as the master and then proceeding to steps #3I to #3N the association with backup CEs CE#2 to CE#N. If the FE fails to connect or associate with some CEs, the FE MAY flag them as unreachable to avoid continuous attempts to connect. The FE MAY retry to reassociate with unreachable CEs when possible.

When the master CE for any reason is considered to be down, then the FE MUST try to find the first associated CE from the list of all CEs in a round-robin fashion.

If the FE is unable to find an associated FE in its list of CEs, then it MUST attempt to connect and associate with the first from the list of all CEs and continue in a round-robin fashion until it connects and associates with a CE.

Once the FE selects an associated CE to use as the new master, the FE issues a PrimaryCEDown Event Notification to all associated CEs to notify them that the last primary CE went down (and what its identity was); a second event PrimaryCEChanged identifying the new master CE is sent as well to identify which CE the reporting FE considers to be the new master.

In most HA architectures there exists the possibility of split-brain. However, since in our setup the FE will never accept any configuration messages from any other than the master CE, we consider the FE as fenced against data corruption from the other CEs that consider themselves as the master. The split-brain issue becomes mostly a CE-CE communication problem which is considered to be out of scope.

By virtue of having multiple CE connections, the FE switchover to a new master CE will be relatively much faster. The overall effect is improving the NE recovery time in case of communication failure or faults of the master CE. This satisfies the requirement we set to achieve.

## **5. IANA Considerations**

XXX: This document updates an IANA registered FE Protocol object Logical Functional Block (LFB). At minimal when it becomes RFC we should update <https://www.iana.org/assignments/forces/forces.xml> section on FEPO.

## **6. Security Considerations**

Security consideration as defined in [section 9 of \[RFC5810\]](#) applies.



## [7. References](#)

### [7.1. Normative References](#)

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.
- [RFC5810] Doria, A., Hadi Salim, J., Haas, R., Khosravi, H., Wang, W., Dong, L., Gopal, R., and J. Halpern, "Forwarding and Control Element Separation (ForCES) Protocol Specification", [RFC 5810](#), March 2010.

### [7.2. Informative References](#)

- [RFC3654] Khosravi, H. and T. Anderson, "Requirements for Separation of IP Control and Forwarding", [RFC 3654](#), November 2003.
- [RFC3746] Yang, L., Dantu, R., Anderson, T., and R. Gopal, "Forwarding and Control Element Separation (ForCES) Framework", [RFC 3746](#), April 2004.
- [RFC5812] Halpern, J. and J. Hadi Salim, "Forwarding and Control Element Separation (ForCES) Forwarding Element Model", [RFC 5812](#), March 2010.

## [Appendix A. New FEPO version](#)

The xml has been validated against the schema defined in [[RFC5812](#)].

```
<LFBLibrary xmlns="urn:ietf:params:xml:ns:forces:lfbmodel:1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="lfb-schema.xsd" provides="FEPO">
  <!-- XXX -->
  <dataTypeDefs>
    <dataTypeDef>
      <name>CEHBPolyValues</name>
      <synopsis>
        The possible values of CE heartbeat policy
      </synopsis>
      <atomic>
        <baseType>uchar</baseType>
        <specialValues>
          <specialValue value="0">
            <name>CEHBPoly0</name>
            <synopsis>
              The CE will send heartbeats to the FE
              every CEHDI timeout if no other messages
              have been sent since.
```



```

        </synopsis>
      </specialValue>
      <specialValue value="1">
        <name>CEHBPolicy1</name>
        <synopsis>
          The CE will not send heartbeats to the FE
        </synopsis>
      </specialValue>
    </specialValues>
  </atomic>
</dataTypeDef>
<dataTypeDef>
  <name>FEHBPolicyValues</name>
  <synopsis>
    The possible values of FE heartbeat policy
  </synopsis>
  <atomic>
    <baseType>uchar</baseType>
    <specialValues>
      <specialValue value="0">
        <name>FEHBPolicy0</name>
        <synopsis>
          The FE will not generate any heartbeats to the CE
        </synopsis>
      </specialValue>
      <specialValue value="1">
        <name>FEHBPolicy1</name>
        <synopsis>
          The FE generates heartbeats to the CE every FEHI
          if no other messages have been sent to the CE.
        </synopsis>
      </specialValue>
    </specialValues>
  </atomic>
</dataTypeDef>
<dataTypeDef>
  <name>FERestartPolicyValues</name>
  <synopsis>
    The possible values of FE restart policy
  </synopsis>
  <atomic>
    <baseType>uchar</baseType>
    <specialValues>
      <specialValue value="0">
        <name>FERestartPolicy0</name>
        <synopsis>
          The FE restart restats its state from scratch
        </synopsis>

```





```

        </specialValue>
      </specialValues>
    </atomic>
  </dataTypeDef>
  <dataTypeDef>
    <name>HAModeValues</name>
    <synopsis>
      The possible values of HA modes
    </synopsis>
    <atomic>
      <baseType>uchar</baseType>
      <specialValues>
        <specialValue value="0">
          <name>NoHA</name>
          <synopsis>
            The FE is not running in HA mode
          </synopsis>
        </specialValue>
        <specialValue value="1">
          <name>ColdStandby</name>
          <synopsis>
            The FE is running in HA mode cold Standby
          </synopsis>
        </specialValue>
        <specialValue value="2">
          <name>HotStandby</name>
          <synopsis>
            The FE is running in HA mode hot Standby
          </synopsis>
        </specialValue>
      </specialValues>
    </atomic>
  </dataTypeDef>
  <dataTypeDef>
    <name>CEFailoverPolicyValues</name>
    <synopsis>
      The possible values of CE failover policy
    </synopsis>
    <atomic>
      <baseType>uchar</baseType>
      <specialValues>
        <specialValue value="0">
          <name>CEFailoverPolicy0</name>
          <synopsis>
            The FE should stop functioning immediate and
            transition to the FE OperDisable state
          </synopsis>
        </specialValue>

```



```
<specialValue value="1">
  <name>CEFailoverPolicy1</name>
  <synopsis>
    The FE should continue forwarding even without an
    associated CE for CEFTI. The FE goes to FE
    OperDisable when the CEFTI expires and no
    association. Requires graceful restart support.
  </synopsis>
</specialValue>
</specialValues>
</atomic>
</dataTypeDef>
<dataTypeDef>
  <name>FEHACapab</name>
  <synopsis>
    The supported HA features
  </synopsis>
  <atomic>
    <baseType>uchar</baseType>
    <specialValues>
      <specialValue value="0">
        <name>GracefullRestart</name>
        <synopsis>
          The FE supports Graceful Restart
        </synopsis>
      </specialValue>
      <specialValue value="1">
        <name>HA</name>
        <synopsis>
          The FE supports HA
        </synopsis>
      </specialValue>
    </specialValues>
  </atomic>
</dataTypeDef>
<dataTypeDef>
  <name>CEStatusType</name>
  <synopsis>Status values. Status for each CE</synopsis>
  <atomic>
    <baseType>uchar</baseType>
    <specialValues>
      <specialValue value="0">
        <name>Disconnected</name>
        <synopsis>No connection attempt with the CE yet
        </synopsis>
      </specialValue>
      <specialValue value="1">
        <name>Connected</name>
```



```
        <synopsis>The FE connection with the CE at the TML
            has been completed
        </synopsis>
    </specialValue>
    <specialValue value="2">
        <name>Associated</name>
        <synopsis>The FE has associated with the CE
        </synopsis>
    </specialValue>
    <specialValue value="3">
        <name>IsMaster</name>
        <synopsis>The CE is the master (and associated)
        </synopsis>
    </specialValue>
    <specialValue value="4">
        <name>LostConnection</name>
        <synopsis>The FE was associated with the CE but
            lost the connection
        </synopsis>
    </specialValue>
    <specialValue value="5">
        <name>Unreachable</name>
        <synopsis>The CE is deemed as unreachable by the FE
        </synopsis>
    </specialValue>
</specialValues>
</atomic>
</dataTypeDef>
<dataTypeDef>
    <name>StatisticsType</name>
    <synopsis>Statistics Definition</synopsis>
    <struct>
        <component componentID="1">
            <name>RecvPackets</name>
            <synopsis>Packets Received</synopsis>
            <typeRef>uint64</typeRef>
        </component>
        <component componentID="2">
            <name>RecvErrPackets</name>
            <synopsis>Packets Received from CE with errors
            </synopsis>
            <typeRef>uint64</typeRef>
        </component>
        <component componentID="3">
            <name>RecvBytes</name>
            <synopsis>Bytes Received from CE</synopsis>
            <typeRef>uint64</typeRef>
        </component>
    </struct>
</dataTypeDef>
```



```
<component componentID="4">
  <name>RecvErrBytes</name>
  <synopsis>Bytes Received from CE in Error</synopsis>
  <typeRef>uint64</typeRef>
</component>
<component componentID="5">
  <name>TxmitPackets</name>
  <synopsis>Packets Transmitted to CE</synopsis>
  <typeRef>uint64</typeRef>
</component>
<component componentID="6">
  <name>TxmitErrPackets</name>
  <synopsis>
    Packets Transmitted to CE that incurred
    errors
  </synopsis>
  <typeRef>uint64</typeRef>
</component>
<component componentID="7">
  <name>TxmitBytes</name>
  <synopsis>Bytes Transmitted to CE</synopsis>
  <typeRef>uint64</typeRef>
</component>
<component componentID="8">
  <name>TxmitErrBytes</name>
  <synopsis>Bytes Transmitted to CE incurring errors
  </synopsis>
  <typeRef>uint64</typeRef>
</component>
</struct>
</dataTypeDef>
<dataTypeDef>
  <name>AllCEType</name>
  <synopsis>Table Type for AllCE component</synopsis>
  <struct>
    <component componentID="1">
      <name>CEID</name>
      <synopsis>ID of the CE</synopsis>
      <typeRef>uint32</typeRef>
    </component>
    <component componentID="2">
      <name>Statistics</name>
      <synopsis>Statistics per CE</synopsis>
      <typeRef>StatisticsType</typeRef>
    </component>
    <component componentID="3">
      <name>CEStatus</name>
      <synopsis>Status of the CE</synopsis>
```





```
        <typeRef>CEStatusType</typeRef>
      </component>
    </struct>
  </dataTypeDef>
</dataTypeDefs>
<LFBClassDefs>
  <LFBClassDef LFBClassID="2">
    <name>FEPO</name>
    <synopsis>
      The FE Protocol Object, with new CEHA
    </synopsis>
    <version>1.1</version>
    <components>
      <component componentID="1" access="read-only">
        <name>CurrentRunningVersion</name>
        <synopsis>Currently running ForCES version</synopsis>
        <typeRef>uchar</typeRef>
      </component>
      <component componentID="2" access="read-only">
        <name>FEID</name>
        <synopsis>Unicast FEID</synopsis>
        <typeRef>uint32</typeRef>
      </component>
      <component componentID="3" access="read-write">
        <name>MulticastFEIDs</name>
        <synopsis>
          the table of all multicast IDs
        </synopsis>
        <array type="variable-size">
          <typeRef>uint32</typeRef>
        </array>
      </component>
      <component componentID="4" access="read-write">
        <name>CEHBPpolicy</name>
        <synopsis>
          The CE Heartbeat Policy
        </synopsis>
        <typeRef>CEHBPpolicyValues</typeRef>
      </component>
      <component componentID="5" access="read-write">
        <name>CEHDI</name>
        <synopsis>
          The CE Heartbeat Dead Interval in millisecs
        </synopsis>
        <typeRef>uint32</typeRef>
      </component>
      <component componentID="6" access="read-write">
        <name>FEHBPpolicy</name>
```



```
<synopsis>
    The FE Heartbeat Policy
</synopsis>
<typeRef>FEHBPolicyValues</typeRef>
</component>
<component componentID="7" access="read-write">
    <name>FEHI</name>
    <synopsis>
        The FE Heartbeat Interval in millisecs
    </synopsis>
    <typeRef>uint32</typeRef>
</component>
<component componentID="8" access="read-write">
    <name>CEID</name>
    <synopsis>
        The Primary CE this FE is associated with
    </synopsis>
    <typeRef>uint32</typeRef>
</component>
<component componentID="9" access="read-write">
    <name>BackupCEs</name>
    <synopsis>
        The table of all backup CEs other than the
        primary
    </synopsis>
    <array type="variable-size">
        <typeRef>uint32</typeRef>
    </array>
</component>
<component componentID="10" access="read-write">
    <name>CEFailoverPolicy</name>
    <synopsis>
        The CE Failover Policy
    </synopsis>
    <typeRef>CEFailoverPolicyValues</typeRef>
</component>
<component componentID="11" access="read-write">
    <name>CEFTI</name>
    <synopsis>
        The CE Failover Timeout Interval in millisecs
    </synopsis>
    <typeRef>uint32</typeRef>
</component>
<component componentID="12" access="read-write">
    <name>FERestartPolicy</name>
    <synopsis>
        The FE Restart Policy
    </synopsis>
```



```
<typeRef>FERestartPolicyValues</typeRef>
</component>
<component componentID="13" access="read-write">
  <name>LastCEID</name>
  <synopsis>
    The Primary CE this FE was last associated
    with
  </synopsis>
  <typeRef>uint32</typeRef>
</component>
<component componentID="14" access="read-write">
  <name>HAMode</name>
  <synopsis>
    The HA mode used
  </synopsis>
  <typeRef>HAModeValues</typeRef>
</component>
<component componentID="15" access="read-only">
  <name>AllCEs</name>
  <synopsis>The table of all CEs</synopsis>
  <array type="variable-size">
    <typeRef>AllCEType</typeRef>
  </array>
</component>
</components>
<capabilities>
  <capability componentID="30">
    <name>SupportableVersions</name>
    <synopsis>
      the table of ForCES versions that FE supports
    </synopsis>
    <array type="variable-size">
      <typeRef>uchar</typeRef>
    </array>
  </capability>
  <capability componentID="31">
    <name>HACapabilities</name>
    <synopsis>
      the table of HA capabilities the FE supports
    </synopsis>
    <array type="variable-size">
      <typeRef>FEHACapab</typeRef>
    </array>
  </capability>
</capabilities>
<events baseID="61">
  <event eventID="1">
    <name>PrimaryCEDown</name>
```



```
<synopsis>
  The primary CE has changed
</synopsis>
<eventTarget>
  <eventField>LastCEID</eventField>
</eventTarget>
<eventChanged/>
<eventReports>
  <eventReport>
    <eventField>LastCEID</eventField>
  </eventReport>
</eventReports>
</event>
<event eventID="2">
  <name>PrimaryCEChanged</name>
  <synopsis>A New primary CE has been selected
</synopsis>
  <eventTarget>
    <eventField>CEID</eventField>
  </eventTarget>
  <eventChanged/>
  <eventReports>
    <eventReport>
      <eventField>CEID</eventField>
    </eventReport>
  </eventReports>
</event>
</events>
</LFBClassDef>
</LFBClassDefs>
</LFBLibrary>
```

#### Authors' Addresses

Kentaro Ogawa  
NTT Corporation  
3-9-11 Midori-cho  
Musashino-shi, Tokyo 180-8585  
Japan

Email: [ogawa.kentaro@lab.ntt.co.jp](mailto:ogawa.kentaro@lab.ntt.co.jp)





Weiming Wang  
Zhejiang Gongshang University  
149 Jiaogong Road  
Hangzhou 310035  
P.R.China

Phone: +86-571-88057712  
Email: wmwang@mail.zjgsu.edu.cn

Evangelos Haleplidis  
University of Patras  
Panepistimioupoli Patron  
Patras 26504  
Greece

Email: ehalep@ece.upatras.gr

Jamal Hadi Salim  
Mojatatu Networks  
Suite 400, 303 Moodie Dr.  
Ottawa, Ontario K2H 9R4  
Canada

Email: hadi@mojatatu.com