

Workgroup: Network Working Group  
Internet-Draft: draft-chen-bier-te-lan-02  
Published: 22 February 2022  
Intended Status: Standards Track  
Expires: 26 August 2022  
Authors: H. Chen      M. McBride      A. Wang  
         Futurewei      Futurewei      China Telecom  
         G. Mishra      L. Liu      X. Liu  
         Verizon Inc.      Fujitsu      Volta Networks  
**BIER-TE for Broadcast Link**

## Abstract

This document describes extensions to "Bit Index Explicit Replication Traffic Engineering" (BIER-TE) for supporting LANs (i.e., broadcast links). For a multicast packet with an explicit point-to-multipoint (P2MP) path traversing LANs, the packet is replicated and forwarded statelessly along the path.

## Requirements Language

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 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

## 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 <https://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 26 August 2022.

## Copyright Notice

Copyright (c) 2022 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 (<https://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 Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

## Table of Contents

- [1. Introduction](#)
  - [1.1. Terminology](#)
- [2. Example Application of Current BIER-TE with LAN](#)
  - [2.1. Example BIER-TE Topology with LAN](#)
  - [2.2. BIER-TE BIFT on BFR](#)
  - [2.3. Example P2MP Path with LAN](#)
- [3. Improved BIER-TE with LAN](#)
  - [3.1. New BP Assignments for LAN](#)
  - [3.2. Improved BIER-TE BIFT on BFR](#)
  - [3.3. Updated Forwarding Procedure](#)
- [4. Example Application of Improved BIER-TE](#)
- [5. Security Considerations](#)
- [6. IANA Considerations](#)
- [7. Acknowledgements](#)
- [8. References](#)
  - [8.1. Normative References](#)
  - [8.2. Informative References](#)
- [Authors' Addresses](#)

## 1. Introduction

[[I-D.ietf-bier-te-arch](#)] introduces Bit Index Explicit Replication (BIER) Traffic/Tree Engineering (BIER-TE). It is an architecture for per-packet stateless explicit point to multipoint (P2MP) multicast path/tree. A Bit-Forwarding Router (BFR) in a BIER-TE domain has a BIER-TE Bit Index Forwarding Table (BIFT). A BIER-TE BIFT on a BFR comprises a forwarding entry for a BitPosition (BP) assigned to each of the adjacencies of the BFR. If the BP represents a forward connected adjacency, the forwarding entry for the BP forwards the multicast packet with the BP to the directly connected BFR neighbor of the adjacency. If the BP represents a BFER (i.e., egress node) or say a local decap adjacency, the forwarding entry for the BP decapsulates the multicast packet with the BP and passes a copy of the payload of the packet to the packet's NextProto within the BFR.

In [[I-D.ietf-bier-te-arch](#)], for a LAN, the adjacency to each neighboring BFR on the LAN is given a unique BitPosition. The

adjacency of this BitPosition is a forward connected adjacency towards the BFR and this BitPosition is populated into the BIFT of all the other BFRs on that LAN. This solution for a LAN does not work in some cases.

For a packet with an explicit point-to-multipoint (P2MP) path, if the path traverses some BFRs/nodes on a LAN, each of these BFRs/nodes on the LAN may receive duplicated packets. Thus some of the egress nodes will receive duplicated packets.

This document proposes a solution for LANs to resolve this issue. For a packet with an explicit P2MP path traversing LANs (i.e., broadcast links), the packet is replicated and forwarded statelessly along the path. Each of the egress nodes of the path will not receive any duplicated packet.

### 1.1. Terminology

**BIER:** Bit Index Explicit Replication.

**BIER-TE:** BIER Traffic Engineering.

**BFR:** Bit-Forwarding Router.

**BFIR:** Bit-Forwarding Ingress Router.

**BFER:** Bit-Forwarding Egress Router.

**BFR-id:** BFR Identifier. It is a number in the range [1,65535].

**BFR-NBR:** BFR Neighbor.

**BFR-prefix:** An IP address (either IPv4 or IPv6) of a BFR.

**BIRT:** Bit Index Routing Table. It is a table that maps from the BFR-id (in a particular sub-domain) of a BFER to the BFR-prefix of that BFER, and to the BFR-NBR on the path to that BFER.

**BIFT:** Bit Index Forwarding Table.

**IGP:** Interior Gateway Protocol.

**LSDB:** Link State DataBase.

**OSPF:** Open Shortest Path First.

**IS-IS:** Intermediate System to Intermediate System.

## 2. Example Application of Current BIER-TE with LAN

This section illustrates an example application of the current BIER-TE defined in [I-D.ietf-bier-te-arch] to the BIER-TE topology with LAN in Figure 1.

### 2.1. Example BIER-TE Topology with LAN

An example BIER-TE topology with a LAN for a BIER-TE domain is shown in Figure 1. It has 9 nodes/BFRs A, B, C, D, E, F, G, H and K. Nodes/BFRs D, F, E, H, A and K are BFRs and have local decap adjacency BitPositions (BPs for short) 1, 2, 3, 4, 5 and 6 respectively. For simplicity, these BPs are represented by (SI:BitString), where SI = 0 and BitString is of 8 bits. BPs 1, 2, 3, 4, 5 and 6 are represented by 1 (0:00000001), 2 (0:00000010), 3 (0:00000100), 4 (0:00001000), 5 (0:00010000) and 6 (0:00100000) respectively.

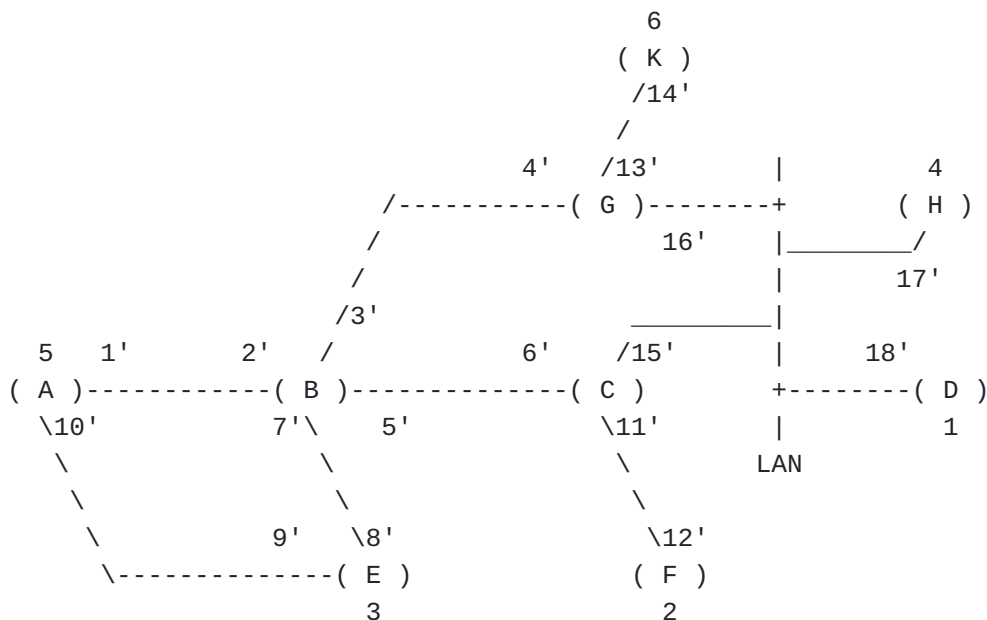


Figure 1: Example BIER-TE Topology with BP to BFR on LAN

The BitPositions for the forward connected adjacencies are represented by  $i'$ , where  $i$  is from 1 to 18. In one option, they are encoded as  $(n+i)$ , where  $n$  is a power of 2 such as 32768. For simplicity, these BitPositions are represented by (SI:BitString), where  $SI = (6 + (i-1)/8)$  and BitString is of 8 bits. BitPositions  $i'$  ( $i$  from 1 to 18) are represented by 1'(6:00000001), 2'(6:00000010), 3'(6:00000100), 4'(6:00001000), 5'(6:00010000), 6'(6:00100000), 7'(6:01000000), 8'(6:10000000), 9'(7:00000001), 10'(7:00000010), . . . , 16'(7:10000000), 17'(8:00000001), 18'(8:00000010).

For a link between two nodes X and Y, there are two BitPositions for two forward connected adjacencies. These two forward connected adjacency BitPositions are assigned on nodes X and Y respectively. The BitPosition assigned on X is the forward connected adjacency of Y. The BitPosition assigned on Y is the forward connected adjacency of X.

For example, for the link between nodes B and C in the figure, two forward connected adjacency BitPositions 5' and 6' are assigned to two ends of the link. BitPosition 5' is assigned on node B to B's end of the link. It is the forward connected adjacency of node C. BitPosition 6' is assigned on node C to C's end of the link. It is the forward connected adjacency of node B.

For a LAN (i.e., broadcast link) connecting nodes X1, X2, ..., Xm, there are m BitPositions for m forward connected adjacencies. These m forward connected adjacency BitPositions are assigned on nodes X1, X2, ..., Xm respectively.

For the LAN connecting 4 nodes C, G, H and D in the figure, 4 forward connected adjacency BitPositions 15', 16', 17' and 18' are assigned to C, G, H and D respectively.

## **2.2. BIER-TE BIFT on BFR**

Every BFR in a BIER-TE domain/topology has a BIER-TE BIFT. This section shows the BIER-TE BIFT on every BFR/node of the BIER-TE topology with LAN in [Figure 1](#).

For the BIER-TE topology in [Figure 1](#), each of 9 nodes/BFRs A, B, C, D, E, F, G, H and K has its BIER-TE BIFT for the topology. The BIFT on a BFR comprises a forwarding entry for each of the adjacencies of the BFR.

The BIER-TE BIFT on BFR A (i.e., node A) is shown in [Figure 2](#). There are three adjacencies of A. The 1st one is the forward connected adjacency from A to B (represented by BP 2'); the 2nd is the forward connected adjacency from A to E (represented by BP 9'); the 3rd is the local decap adjacency (represented by BP 5) for BFER (i.e., egress) A. The BIFT on A has three forwarding entries.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
2'(6:00000010)	fw-connected	B
9'(7:00000001)	fw-connected	E
5 (0:00010000)	local-decap	

Figure 2: BIER-TE BIFT on BFR A

The 1st forwarding entry in the BIFT is for BitPosition 2', which is the forward connected adjacency from A to B. For a multicast packet with BitPosition 2', which indicates that the P2MP path in the packet traverses the adjacency from A to B, the forwarding entry forwards the packet to B along the link from A to B.

The 2nd forwarding entry in the BIFT is for BitPosition 9', which is the forward connected adjacency from A to E. For a multicast packet with BitPosition 9', which indicates that the P2MP path in the packet traverses the adjacency from A to E, the forwarding entry forwards the packet to E along the link from A to E.

The 3rd forwarding entry in the BIFT locally decapsulates a multicast packet with BitPosition 5 and passes a copy of the payload of the packet to the packet's NextProto. It is for BitPosition 5, which is the local decap adjacency for BFER (i.e., egress) A. For a multicast packet with BitPosition 5, which indicates that the P2MP path in the packet has node A as one of its destinations (i.e., egress nodes), the forwarding entry decapsulates the packet and passes a copy of the payload of the packet to the packet's NextProto within node A.

The BIER-TE BIFT on BFR B (i.e., node B) is shown in [Figure 3](#). There are four forward connected adjacencies of B. They are the forward connected adjacencies from B to A (represented by BP 1'), B to G (represented by BP 4'), B to C (represented by BP 6') and B to E (represented by BP 8') respectively. The BIFT on B has four forwarding entries for these adjacencies.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
1'(6:00000001)	fw-connected	A
4'(6:00001000)	fw-connected	G
6'(6:00100000)	fw-connected	C
8'(6:10000000)	fw-connected	E

Figure 3: BIER-TE BIFT on BFR B

The 1st forwarding entry in the BIFT is for BitPosition 1', which is the forward connected adjacency from B to A. For a multicast packet with BitPosition 1', which indicates that the P2MP path in the packet traverses the adjacency from B to A, the forwarding entry forwards the packet to A along the link from B to A.

The 2nd forwarding entry in the BIFT is for BitPosition 4', which is the forward connected adjacency from B to G. For a multicast packet with BitPosition 4', which indicates that the P2MP path in the packet traverses the adjacency from B to G, the forwarding entry forwards the packet to G along the link from B to G.

The 3rd forwarding entry in the BIFT is for BitPosition 6', which is the forward connected adjacency from B to C. For a multicast packet with BitPosition 6', which indicates that the P2MP path in the packet traverses the adjacency from B to C, the forwarding entry forwards the packet to C along the link from B to C.

The 4-th forwarding entry in the BIFT is for BitPosition 8', which is the forward connected adjacency from B to E. For a multicast packet with BitPosition 8', which indicates that the P2MP path in the packet traverses the adjacency from B to E, the forwarding entry forwards the packet to E along the link from B to E.

The BIER-TE BIFT on BFR C (i.e., node C) is shown in [Figure 4](#). There are five forward connected adjacencies of C. They are the forward connected adjacencies from C to B (represented by BP 5'), C to F (represented by BP 12'), C to G (represented by BP 14'), C to H (represented by BP 15') and C to D (represented by BP 16') respectively. The BIFT on C has five forwarding entries for these adjacencies.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
5'(6:00010000)	fw-connected	B
12'(7:00001000)	fw-connected	F
16'(7:10000000)	fw-connected	G
17'(8:00000001)	fw-connected	H
18'(8:00000010)	fw-connected	D

Figure 4: BIER-TE BIFT on BFR C

The BIER-TE BIFT on BFR D (i.e., node D) is shown in [Figure 5](#). There are four adjacencies of D. Three of them are the forward connected adjacencies from D to C (represented by BP 15'), D to G (represented by BP 16') and D to H (represented by BP 17') respectively; the other is the local decap adjacency (represented by BP 1) for BFER (i.e., egress) D. The BIFT on D has four forwarding entries for these adjacencies.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
15'(7:01000000)	fw-connected	C
16'(7:10000000)	fw-connected	G
17'(8:00000001)	fw-connected	H
1 (0:00000001)	local-decap	

Figure 5: BIER-TE BIFT on BFR D

The BIER-TE BIFT on BFR E (i.e., node E) is shown in [Figure 6](#). There are three adjacencies of E. Two of them are the forward connected adjacencies from E to B (represented by BP 7') and E to A (represented by BP 10') respectively; the other is the local decap adjacency (represented by BP 3) for BFER (i.e., egress) E. The BIFT on E has three forwarding entries for these adjacencies.



Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
7'(6:01000000)	fw-connected	B
10'(7:00000010)	fw-connected	A
3 (0:000000100)	local-decap	

Figure 6: BIER-TE BIFT on BFR E

The BIER-TE BIFT on BFR F (i.e., node F) is shown in [Figure 7](#). There are two adjacencies of F. The 1st one is the forward connected adjacencies from F to C (represented by BP 11'); the 2nd is the local decap adjacency (represented by BP 2) for BFER (i.e., egress) F. The BIFT on F has two forwarding entries for these adjacencies.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
11'(7:000000100)	fw-connected	C
2 (0:000000010)	local-decap	

Figure 7: BIER-TE BIFT on BFR F

The BIER-TE BIFT on BFR G (i.e., node G) is shown in [Figure 8](#). There are four forward connected adjacencies of G. They are the adjacencies from G to B (represented by BP 3'), G to C (represented by BP 13'), G to H (represented by BP 15') and G to D (represented by BP 16') respectively. The BIFT on G has four forwarding entries for these adjacencies.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
3'(6:00000100)	fw-connected	B
14'(7:00100000)	fw-connected	K
15'(7:01000000)	fw-connected	C
17'(8:00000001)	fw-connected	H
18'(8:00000010)	fw-connected	D

Figure 8: BIER-TE BIFT on BFR G

The BIER-TE BIFT on BFR H (i.e., node H) is shown in [Figure 9](#). There are four adjacencies of H. Three of them are the forward connected adjacencies from H to C (represented by BP 15'), H to G (represented by BP 16') and H to D (represented by BP 18') respectively; the other is the local decap adjacency (represented by BP 4) for BFER (i.e., egress) H. The BIFT on H has four forwarding entries for these adjacencies.

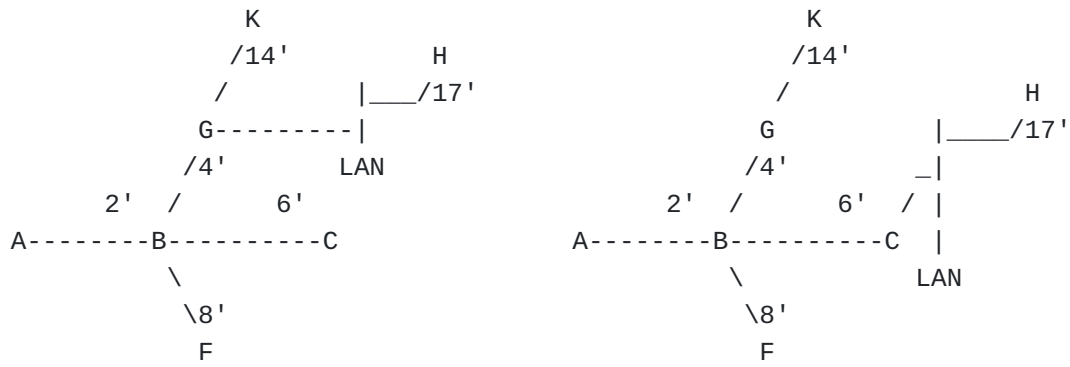
Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
15'(7:01000000)	fw-connected	C
16'(7:10000000)	fw-connected	G
18'(8:00000010)	fw-connected	D
4 (0:00001000)	local-decap	

Figure 9: BIER-TE BIFT on BFR H

### 2.3. Example P2MP Path with LAN

This section presents the issue about receiving duplicated packets at BFER H for any explicit P2MP path/tree from BFIR A to BFERs K, H and F in [Figure 1](#) with minimum height of the tree, which is 3 (hops). Any path will go through the LAN in order to reach BFER H.

There are only following explicit P2MP paths from A to K, H and D.



Path 1 from A to K, H and F

Path 2 from A to K, H and F

Figure 10: All explicit paths with height 3 from A to K,H and F

Path 1 and path 2 are represented by {2', 4', 6', 12', 14', 17', 2, 4, 6}. Path 1 traverses the link/adjacency from A to B (indicated by BP 2'), the link/adjacency from B to G (indicated by BP 4'), the link/adjacency from B to C (indicated by BP 6'), the link/adjacency from G to K (indicated by BP 14'), the link/adjacency from G to H (indicated by BP 17') [the link/adjacency from C to H (also indicated by BP 17') for Path 2], and the link/adjacency from C to F (indicated by BP 12'). Path 1 is represented by {2', 4', 6', 12', 14', 17', 2, 4, 6}. Path 2 has the same representation. The packet at A has this representation.

For the packet with the P2MP path, A forwards the packet to B according to the forwarding entry for BP 2' in its BIFT.

After receiving the packet from A, B forwards the packet to G and C according to the forwarding entries for BPs 4' and 6' in B's BIFT respectively. The packet received by G has path {12', 14', 17', 2, 4, 6}. The packet received by C has path {12', 14', 17', 2, 4, 6}.

After receiving the packet from B, G sends a copy of the packet to K according to the forwarding entry for BP 14' in G's BIFT, and another copy of the packet to H according to the forwarding entry for BP 17' in G's BIFT.

After receiving the packet from B, C copies and sends the packet to H and F according to the forwarding entries for BPs 17' and 12' in C's BIFT respectively.

Egress node H of the P2MP path receives the duplicated packets. One packet is from G, and the same copy is from C.

The solution proposed for LANs in this document resolve this issue. For a packet with an explicit P2MP path traversing LANs (i.e., broadcast links), the packet is replicated and forwarded statelessly

along the path. Each of the egress nodes of the path will not receive any duplicated packet.

### 3. Improved BIER-TE with LAN

#### 3.1. New BP Assignments for LAN

For all the nodes/BFRs attached to a LAN (i.e., broadcast link), it is assumed that they are connected a pseudo node. In one implementation, the pseudo node is the Designated Router (DR) of the LAN in OSPF or the Designated Intermediate System (DIS) of the LAN in IS-IS.

For the connection between the pseudo node and each of the nodes/BFRs attached to a LAN, two BPs are assigned to it. One is for the adjacency from the BFR to the pseudo node, the other is for the adjacency from the pseudo node to the BFR.

The adjacency from a BFR to the pseudo node is called a LAN adjacency. The adjacency from the pseudo node to a BFR is a forward connected adjacency.

For example, suppose that the pseudo node for the LAN in [Figure 1](#) is Px. The BP assignments for the LAN (i.e., connections between Px and BFRs C, G, H and D) are illustrated in [Figure 11](#).

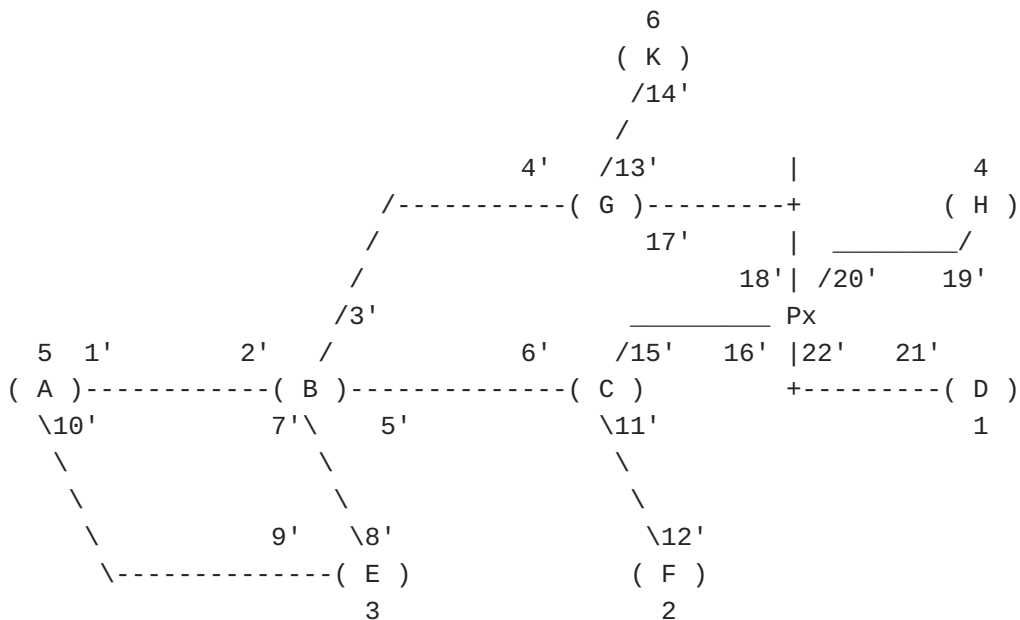


Figure 11: Example BIER-TE Topology with BPs for LAN

The connection/adjacency from Px to C is assigned BP 15', and the connection/adjacency from C to Px is assigned BP 16'.

The connection/adjacency from Px to G is assigned BP 17', and the connection/adjacency from G to Px is assigned BP 18'.

The connection/adjacency from Px to H is assigned BP 19', and the connection/adjacency from H to Px is assigned BP 20'.

The connection/adjacency from Px to D is assigned BP 21', and the connection/adjacency from D to Px is assigned BP 22'.

In an alternative, all the nodes/BFRs attached to a LAN are assumed fully connected each other (i.e., they are fully meshed). For a connection between any two BFRs on the LAN, two forward connected adjacencies are assigned to the two ends of the connection.

For example, there are four BFRs C, G, H and D attached to the LAN in [Figure 1](#). There are six connections among these four BFRs. They are connections between C and G, C and H, C and D, G and H, G and D, H and D. Twelve BPs are needed for these six connections.

In general, for  $n$  BFRs attached to a LAN, there are  $n*(n-1)/2$  connections among these  $n$  BFRs and  $n*(n-1)$  BPs are needed for these connections. This may not be scalable. But for this alternative, the BIER-TE BIFT on a BFR needs not to be changed except for considering the full mesh connections among the BFRs attached to a LAN.

### 3.2. Improved BIER-TE BIFT on BFR

Each BFR in a BIER-TE domain has a BIER-TE BIFT. For a BFR not attached to any LAN, the BIER-TE BIFT on the BFR is the same as before. For a BFR attached to a LAN, its BIER-TE BIFT is changed for considering the LAN.

For example, BFRs C, G, H and D are attached to a LAN in [Figure 1](#). The BIER-TE BIFT on each of these four BFRs is changed for the new BP assignments for the LAN in [Figure 11](#).

For a BFR attached to a LAN, suppose that the pseudo node for the LAN is Px. The improved BIER-TE BIFT on the BFR comprises a forwarding entry for the LAN adjacency from the BFR to Px and a secondary BIFT for Px. The secondary BIFT for Px on the BFR contains a forwarding entry for each of the forward connected adjacencies from Px to the BFRs attached to the LAN except for the adjacency from Px to the BFR.

For example, the improved BIER-TE BIFT on BFR C is illustrated in [Figure 12](#). It comprises the forwarding entry for the LAN adjacency from C to Px (indicated by BP 16') and the secondary BIFT for Px on BFR C. The secondary BIFT contains three forwarding entries for three forward connected adjacencies from Px to G (indicated by 17'),

Px to H (indicated by 19') and Px to D (indicated by 21') respectively.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
17'(8:00000001)	fw-connected	G
19'(8:00000100)	fw-connected	H
21'(8:00010000)	fw-connected	D

Secondary BIFT for Px on BFR C

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
5'(6:00010000)	fw-connected	B
12'(7:00001000)	fw-connected	F
16'(7:10000000)	lan-connected	Px

Figure 12: Improved BIER-TE BIFT on BFR C

The improved BIER-TE BIFT on BFR G is illustrated in [Figure 13](#). It comprises the forwarding entry for the LAN adjacency from G to Px (indicated by BP 18') and the secondary BIFT for Px on BFR G. The secondary BIFT contains three forwarding entries for three forward connected adjacencies from Px to C (indicated by 15'), Px to H (indicated by 19') and Px to D (indicated by 21') respectively.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
15'(7:01000000)	fw-connected	C
19'(8:00000100)	fw-connected	H
21'(8:00010000)	fw-connected	D

Secondary BIFT for Px on BFR G

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
3'(6:00000100)	fw-connected	B
14'(7:00100000)	fw-connected	K
18'(8:00000010)	lan-connected	Px

Figure 13: Improved BIER-TE BIFT on BFR G

The improved BIER-TE BIFT on BFR H is illustrated in [Figure 14](#). It comprises the forwarding entry for the LAN adjacency from H to Px (indicated by BP 20') and the secondary BIFT for Px on BFR H. The secondary BIFT contains three forwarding entries for three forward connected adjacencies from Px to C (indicated by 15'), Px to G (indicated by 17') and Px to D (indicated by 21') respectively.

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
15'(7:01000000)	fw-connected	C
17'(8:00000001)	fw-connected	G
21'(8:00010000)	fw-connected	D

Secondary BIFT for Px on BFR H

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
4 (0:00001000)	local-decap	
20'(8:00001000)	lan-connected	Px

Figure 14: Improved BIER-TE BIFT on BFR H

The improved BIER-TE BIFT on BFR D is illustrated in [Figure 15](#). It comprises the forwarding entry for the LAN adjacency from D to Px (indicated by BP 22') and the secondary BIFT for Px on BFR D. The secondary BIFT contains three forwarding entries for three forward connected adjacencies from Px to C (indicated by 15'), Px to G (indicated by 17') and Px to H (indicated by 19') respectively.



Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
15'(7:01000000)	fw-connected	C
17'(8:00000001)	fw-connected	G
19'(8:00000100)	fw-connected	H

Secondary BIFT for Px on BFR D

Adjacency BP (SI:BitString)	Action	BFR-NBR (Next Hop)
1 (0:00000001)	local-decap	
22'(8:00000100)	lan-connected	Px

Figure 15: Improved BIER-TE BIFT on BFR D

### 3.3. Updated Forwarding Procedure

The forwarding procedure defined in [I-D.ietf-bier-te-arch] is updated/enhanced for using an improved BIER-TE BIFT to support BIER-TE with LAN.

The updated procedure is described in Figure 16. For a multicast packet containing the BitString encoding an explicit P2MP path, if the BP in the BitString is for a LAN adjacency to pseudo node Px for the LAN, the updated forwarding procedure on a BFR sends the packet towards Px's next hop nodes on the P2MP path encoded in the packet.

The procedure on a BFR "sends" (i.e., works as sending) the packet with the BP for the LAN adjacency to Px according to the forwarding entry for the BP in the improved BIER-TE BIFT on the BFR. And then it acts on Px to "send" (i.e., works as sending) the packet to each of the Px's next hop nodes that are on the P2MP path using the secondary BIFT for Px.

It obtains the secondary BIFT for Px on the BFR, clears all the BPs for the adjacencies of the BFR including the adjacency from the BFR to Px, copies and sends the packet to each of the Px's next hop nodes on the P2MP path using the secondary BIFT for Px.

For each Px's next hop node on the P2MP path, which is represented by BP j in the packet's BitString, it gets the forwarding entry for BP j from the secondary BIFT for Px, copies the packet, updates the

copy's BitString by clearing all the BPs for Px's adjacencies, and sends the updated copy to the next hop node according to the forwarding entry.

```

Packet = the packet received by BFR;
FOR each BP k (from the rightmost in Packet's BitString) {
    IF BP k is local decap adjacency (or say BP of BFER) {
        Copies Packet, sends the copy to the multicast
        flow overlay and clears bit k in Packet's BitString
    } ELSE IF BP k is forward connected adjacency of the BFR {
        Finds the forwarding entry in the BIER-TE BIFT using BP k,
        Copies Packet, updates the copy's BitString by
        clearing all the BPs for the adjacencies of the BFR,
        and sends the updated copy to BFR-NBR
    } ELSE IF BP k is LAN adjacency to Px {
        Obtains the secondary BIFT for Px,
        Clears all the BPs for the adjacencies of the BFR,
        FOR each BP j (from the rightmost in Packet's BitString) {
            IF BP j is Px's forward connected adjacency {
                Gets the forwarding entry for BP j in the
                secondary BIFT for Px,
                Copies Packet, updates the copy's BitString by
                clearing all the BPs for Px's adjacencies,
                and sends the updated copy to BFR-NBR
            }
        }
    }
}

```

Figure 16: Updated Forwarding Procedure

#### 4. Example Application of Improved BIER-TE

This section illustrates an example application of improved BIER-TE to [Figure 1](#). It shows the forwarding behaviors along an explicit P2MP path in [Figure 11](#) going through the LAN in the figure.

The new BP assignments for the LAN in [Figure 1](#) is shown in [Figure 11](#). The improved BIER-TE BIFT on each of the BFRs attached to the LAN is given in [Section 3.2](#).

The explicit P2MP path traverses the link/adjacency from A to B (indicated by BP 2'), the link/adjacency from B to G (indicated by BP 4') and the link/adjacency from B to C (indicated by BP 6'), the link/adjacency from G to K (indicated by BP 14'), the link/adjacency from G to Px (indicated by BP 18'), the link/adjacency from C to F (indicated by BP 12'), and the link/adjacency from Px to H

(indicated by BP 19'). This path is represented by {2', 4', 6', 12', 14', 18', 19', 2, 4, 6}. The packet at A has this path.

For the packet with the P2MP path, A forwards the packet to B according to the forwarding entry for BP 2' in its BIFT.

After receiving the packet from A, B forwards the packet to G and C according to the forwarding entries for BPs 4' and 6' in B's BIFT respectively. The packet received by G has path {12', 14', 18', 19', 2, 4, 6}. The packet received by C has path {12', 14', 18', 19', 2, 4, 6}.

After receiving the packet from B, G sends a copy of the packet to K according to the forwarding entry for BP 14' in G's improved BIER-TE BIFT and "sends" another copy of the packet to Px according to the forwarding entry for BP 18' in G's improved BIER-TE BIFT. After receiving the packet from G, which has path {12', 19', 2, 4, 6}, Px "sends" the packet to H according to the forwarding entry for BP 19' in the secondary BIFT for Px (a part of G's improved BIER-TE BIFT).

After receiving the packet from G, which has path {12', 19', 2, 4, 6}, K decapsulates the packet and passes a copy of the payload of the packet to the packet's NextProto within node K according to the forwarding entry for BP 6 in K's BIFT.

After receiving the packet from G, which has path {12', 2, 4, 6}, H decapsulates the packet and passes a copy of the payload of the packet to the packet's NextProto within node H according to the forwarding entry for BP 4 in H's improved BIER-TE BIFT.

After receiving the packet from B, which has path {12', 14', 18', 19', 2, 4, 6}, C sends the packet to F according to the forwarding entry for BP 12' in C's improved BIER-TE BIFT.

After receiving the packet from C, which has path {14', 18', 19', 2, 4, 6}, F decapsulates the packet and passes a copy of the payload of the packet to the packet's NextProto within node F according to the forwarding entry for BP 2 in F's BIER-TE BIFT.

Egress node H of the P2MP path does not receive any duplicated packet.

## **5. Security Considerations**

TBD.

## **6. IANA Considerations**

No requirements for IANA.

## 7. Acknowledgements

The authors would like to thank people for their comments to this work.

## 8. References

### 8.1. Normative References

- [I-D.ietf-bier-te-arch] Eckert, T., Menth, M., and G. Cauchie, "Tree Engineering for Bit Index Explicit Replication (BIER-TE)", Work in Progress, Internet-Draft, draft-ietf-bier-te-arch-12, 28 January 2022, <<https://www.ietf.org/archive/id/draft-ietf-bier-te-arch-12.txt>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", RFC 5226, DOI 10.17487/RFC5226, May 2008, <<https://www.rfc-editor.org/info/rfc5226>>.
- [RFC5250] Berger, L., Bryskin, I., Zinin, A., and R. Coltun, "The OSPF Opaque LSA Option", RFC 5250, DOI 10.17487/RFC5250, July 2008, <<https://www.rfc-editor.org/info/rfc5250>>.
- [RFC5286] Atlas, A., Ed. and A. Zinin, Ed., "Basic Specification for IP Fast Reroute: Loop-Free Alternates", RFC 5286, DOI 10.17487/RFC5286, September 2008, <<https://www.rfc-editor.org/info/rfc5286>>.
- [RFC5714] Shand, M. and S. Bryant, "IP Fast Reroute Framework", RFC 5714, DOI 10.17487/RFC5714, January 2010, <<https://www.rfc-editor.org/info/rfc5714>>.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, DOI 10.17487/RFC5880, June 2010, <<https://www.rfc-editor.org/info/rfc5880>>.
- [RFC7356] Ginsberg, L., Previdi, S., and Y. Yang, "IS-IS Flooding Scope Link State PDUs (LSPs)", RFC 7356, DOI 10.17487/RFC7356, September 2014, <<https://www.rfc-editor.org/info/rfc7356>>.
- [RFC7490] Bryant, S., Filsfils, C., Previdi, S., Shand, M., and N. So, "Remote Loop-Free Alternate (LFA) Fast Reroute

(FRR)", RFC 7490, DOI 10.17487/RFC7490, April 2015, <<https://www.rfc-editor.org/info/rfc7490>>.

**[RFC7684]** Psenak, P., Gredler, H., Shakir, R., Henderickx, W., Tantsura, J., and A. Lindem, "OSPFv2 Prefix/Link Attribute Advertisement", RFC 7684, DOI 10.17487/RFC7684, November 2015, <<https://www.rfc-editor.org/info/rfc7684>>.

**[RFC7770]** Lindem, A., Ed., Shen, N., Vasseur, JP., Aggarwal, R., and S. Shaffer, "Extensions to OSPF for Advertising Optional Router Capabilities", RFC 7770, DOI 10.17487/RFC7770, February 2016, <<https://www.rfc-editor.org/info/rfc7770>>.

**[RFC8174]** Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

**[RFC8279]** Wijnands, IJ., Ed., Rosen, E., Ed., Dolganow, A., Przygienda, T., and S. Aldrin, "Multicast Using Bit Index Explicit Replication (BIER)", RFC 8279, DOI 10.17487/RFC8279, November 2017, <<https://www.rfc-editor.org/info/rfc8279>>.

**[RFC8556]** Rosen, E., Ed., Sivakumar, M., Przygienda, T., Aldrin, S., and A. Dolganow, "Multicast VPN Using Bit Index Explicit Replication (BIER)", RFC 8556, DOI 10.17487/RFC8556, April 2019, <<https://www.rfc-editor.org/info/rfc8556>>.

## 8.2. Informative References

**[I-D.eckert-bier-te-frr]** Eckert, T., Cauchie, G., Braun, W., and M. Menth, "Protection Methods for BIER-TE", Work in Progress, Internet-Draft, draft-eckert-bier-te-frr-03, 5 March 2018, <<https://www.ietf.org/archive/id/draft-eckert-bier-te-frr-03.txt>>.

**[I-D.ietf-rtgwg-segment-routing-ti-lfa]**  
Litkowski, S., Bashandy, A., Filsfils, C., Francois, P., Decraene, B., and D. Voyer, "Topology Independent Fast Reroute using Segment Routing", Work in Progress, Internet-Draft, draft-ietf-rtgwg-segment-routing-ti-lfa-08, 21 January 2022, <<https://www.ietf.org/archive/id/draft-ietf-rtgwg-segment-routing-ti-lfa-08.txt>>.

**[I-D.ietf-spring-segment-protection-sr-te-paths]**  
Hegde, S., Bowers, C., Litkowski, S., Xu, X., and F. Xu, "Segment Protection for SR-TE Paths", Work in Progress, Internet-Draft, draft-ietf-spring-segment-protection-sr-

te-paths-02, 21 January 2022, <<https://www.ietf.org/archive/id/draft-ietf-spring-segment-protection-sr-te-paths-02.txt>>.

- [RFC8296] Wijnands, IJ., Ed., Rosen, E., Ed., Dolganow, A., Tantsura, J., Aldrin, S., and I. Meilik, "Encapsulation for Bit Index Explicit Replication (BIER) in MPLS and Non-MPLS Networks", RFC 8296, DOI 10.17487/RFC8296, January 2018, <<https://www.rfc-editor.org/info/rfc8296>>.
- [RFC8401] Ginsberg, L., Ed., Przygienda, T., Aldrin, S., and Z. Zhang, "Bit Index Explicit Replication (BIER) Support via IS-IS", RFC 8401, DOI 10.17487/RFC8401, June 2018, <<https://www.rfc-editor.org/info/rfc8401>>.
- [RFC8444] Psenak, P., Ed., Kumar, N., Wijnands, IJ., Dolganow, A., Przygienda, T., Zhang, J., and S. Aldrin, "OSPFv2 Extensions for Bit Index Explicit Replication (BIER)", RFC 8444, DOI 10.17487/RFC8444, November 2018, <<https://www.rfc-editor.org/info/rfc8444>>.

#### Authors' Addresses

Huaimo Chen  
Futurewei  
Boston, MA,  
United States of America

Email: [Huaimo.chen@futurewei.com](mailto:Huaimo.chen@futurewei.com)

Mike McBride  
Futurewei

Email: [michael.mcbride@futurewei.com](mailto:michael.mcbride@futurewei.com)

Aijun Wang  
China Telecom  
Beiqijia Town, Changping District  
Beijing  
102209  
China

Email: [wangaj3@chinatelecom.cn](mailto:wangaj3@chinatelecom.cn)

Gyan S. Mishra  
Verizon Inc.  
13101 Columbia Pike  
Silver Spring, MD 20904  
United States of America

Phone: [301 502-1347](tel:3015021347)  
Email: [gyan.s.mishra@verizon.com](mailto:gyan.s.mishra@verizon.com)

Lei Liu  
Fujitsu  
United States of America

Email: [liulei.kddi@gmail.com](mailto:liulei.kddi@gmail.com)

Xufeng Liu  
Volta Networks  
McLean, VA  
United States of America

Email: [xufeng.liu.ietf@gmail.com](mailto:xufeng.liu.ietf@gmail.com)