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Tutorial on Bit Index Explicit Replication (BIER)

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1. Fundamentals of IP multicast

2. Introduction to BIER

3. BIER Fast Reroute

4. P4 Implementation

5. Summary

► IP multicast (IPMC) efficiently distributes one-to-many traffic

- Forwarding on tree-like structures
  - Individual distribution trees for different IPMC groups
- Only one packet copy per involved link is sent
- IPMC packet does not carry information about receivers
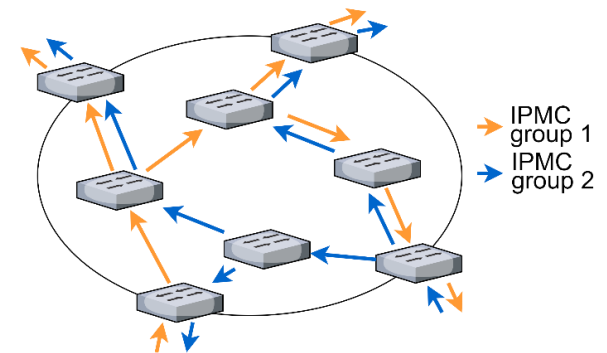
⇒ Traditional IPMC core network requires

1. State per multicast group to know next-hops (NHs) of a packet
2. Signaling in core network when Group subscriptions change

⇒ Scalability of traditional IPMC is limited

Bit Index Explicit Replication (BIER)

► Bit Index Explicit Replication (BIER) is an efficient transport mechanism for IPMC traffic

  ▪ Under development by the IETF
    – 5 RFCs, 27 active drafts and working group documents

► Introduces BIER domain

  ▪ Core routers do not require state per IPMC group
  ▪ Only ingress routers participate in signaling when subscribers change

► Legacy devices do not support BIER

  ▪ SDN allows to implement novel forwarding mechanisms
  ▪ We implemented BIER and BIER fast reroute (BIER-FRR) in P4
    – Software-based for bmv2
    – Hardware-based for Tofino

► **Bit-forwarding ingress routers (BFIRs)**

  ▪ Add BIER header to IPMC packet
    – Contains all destinations
    – Individual BIER header per IPMC group
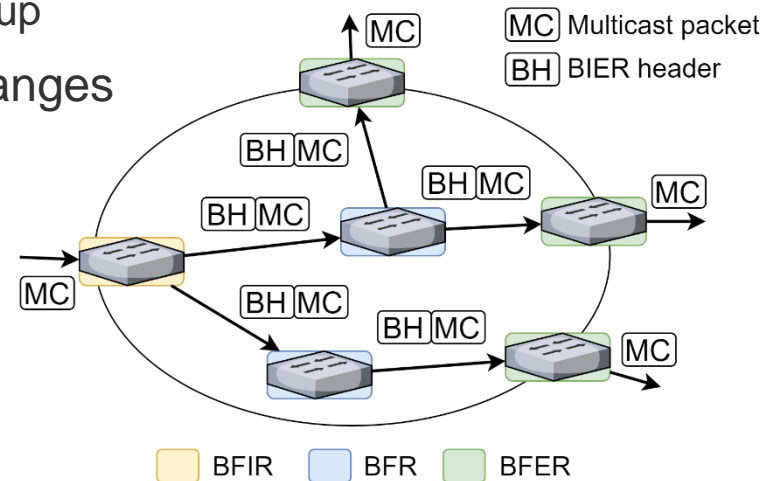 ▪ Receive signals about subscriber changes

► **Bit-forwarding routers (BFRs)**

  ▪ Forward packets to all destinations
  ▪ Bit Index Forwarding Table (BIFT)
  ▪ Entries based on paths from IGP (routing underlay)

  ⇒ Forwarding without IPMC-group dependent state

► **Bit-forwarding egress routers (BFERs)**

  ▪ Remove BIER header

MC Multicast packet
BH BIER header

BFIR   BFR   BFER

► **BFRs process BIER packets as follows**

  ▪ A copy of the BIER packets is forwarded to each NH over which at least one destination of the packet is reached

  ▪ Before a packet copy is forwarded to a NH, all destinations that are reached via other NHs are removed from the packet header (prevents duplicates at receivers)

► **BFRs forward BIER packets to NHs directly on L2**

  ▪ No header of the routing underlay is required

► **BIER RFC specifies processing loop**
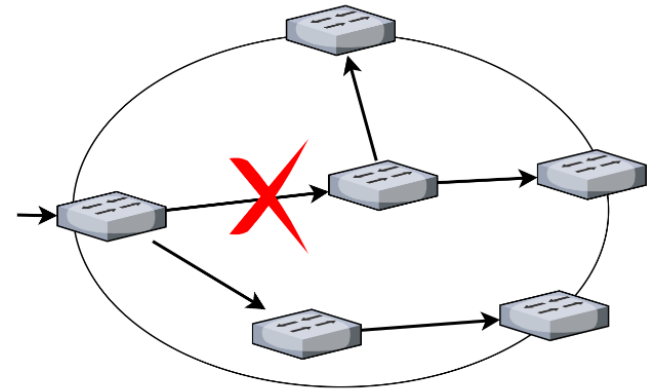
  ▪ Challenging implementation for pipeline-based targets

| x | BIER header with destinations | | BFR | | BFER |
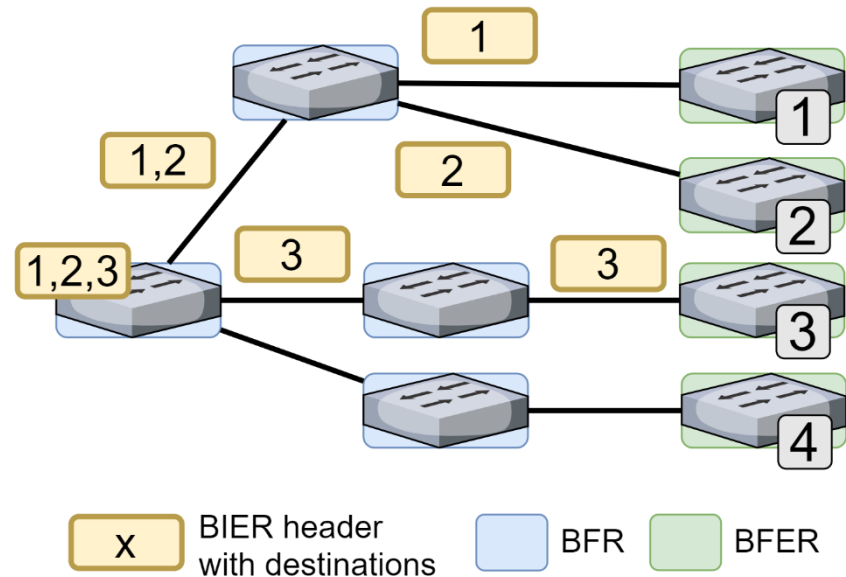
▶ **BFRs cannot reach their neighbors**

- Entire subtree is disconnected

- Only after BIFT has been recomputed, BFRs can forward BIER traffic again

- Possible only after reconvergence of routing underlay

▶ **Routing underlay restores connectivity faster**

- Fast reroute (FRR)

- Faster reconvergence

▶ **BIER fast reroute (BIER-FRR) leverages routing underlay to protect BIER traffic**

- Packet is tunneled through routing underlay to downstream nodes in the distribution tree

 – Benefits from FRR or faster reconvergence in routing underlay

BIER-FRR with Link Protection

► Simple mode that protects only against single link failures

► BFR becomes point of local repair (PLR) when it cannot reach NH

- PLR tunnels BIER packets through routing underlay to NH by adding header of routing underlay to BIER packet

  – Packet is processed as unicast packet
  – Routing underlay may be affected by failure, too
  – FRR or faster reconvergence restore connectivity quickly

- NH removes tunnel header and continues BIER forwarding
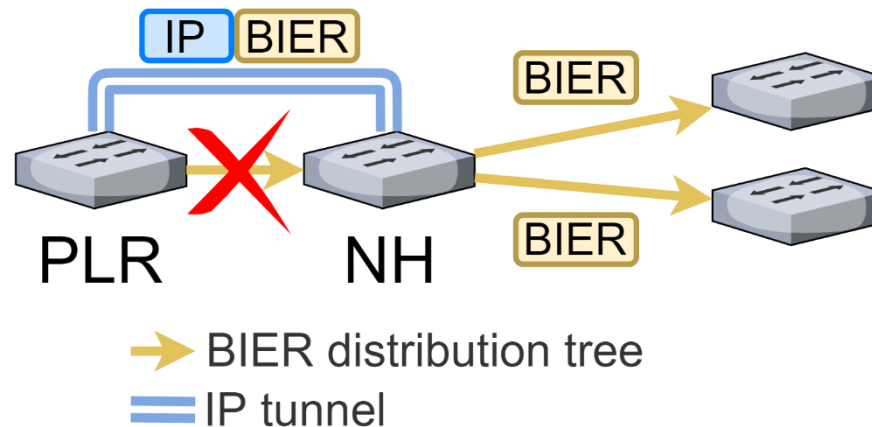

BIER distribution tree
IP tunnel

▶ Node protection for BIER traffic is more complex than link protection

  ▪ If NH fails, affected subtree cannot be reconnected at NH

  ▪ Next reachable downstream nodes in the distribution tree are next-next-hops (NNHs)

▶ BIER packets are tunneled through the routing underlay to all NNHs

  ▪ which should receive a copy of the BIER packet

  ▪ which are on the path towards a destination of the BIER packet

→ BIER distribution tree
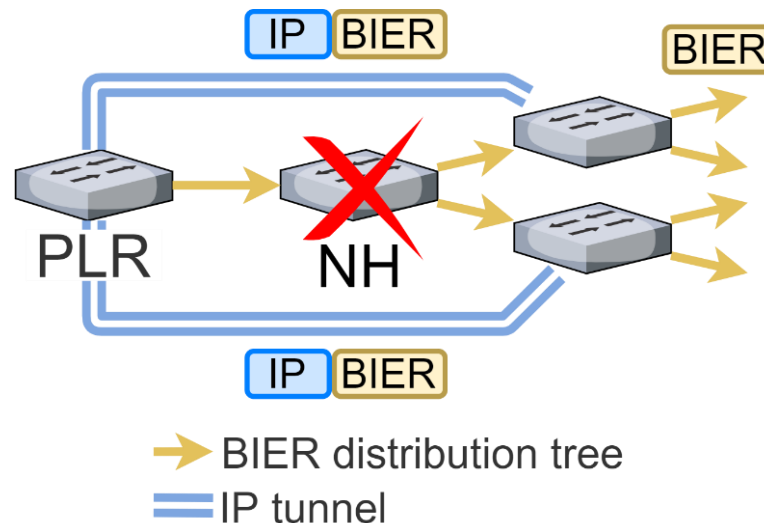
═ IP tunnel

► However: failed NH would have adapted BIER header of BIER packets before forwarding

- PLR bypasses failed NH through a tunnel

⇒ PLR needs to perform additional header adaptations

- Before tunneling a BIER packet to a NNH, destinations which are reached through other NNHs are cleared from the header

| X | BIER header with destinations | | BFR | | BFER |
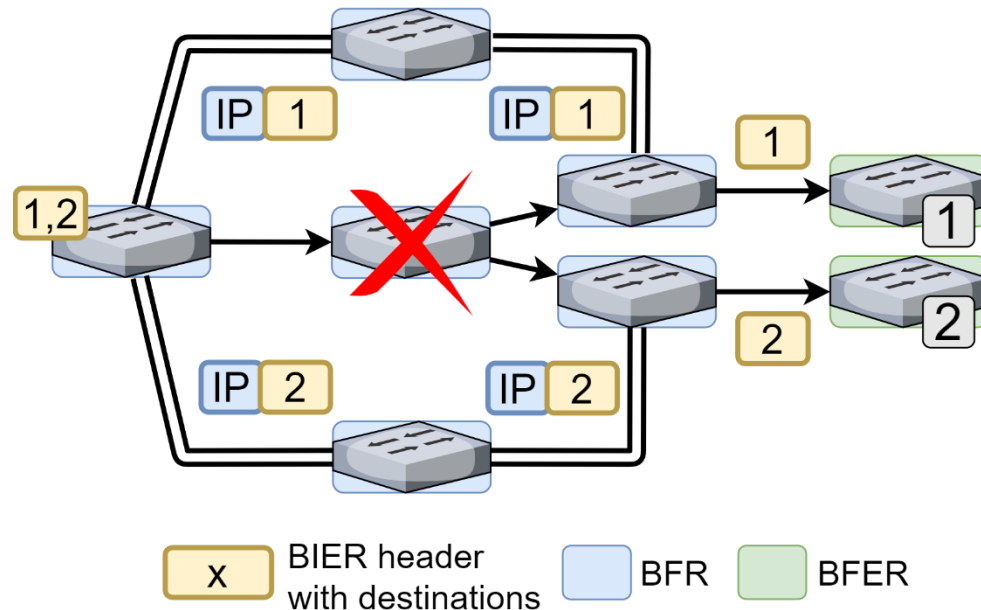
► Implementation of loop-based BIER processing is challanging for pipeline-based targets

- Packet recirculation to process packet again

- Proof-of-concept software implementation for bmv2

  - No quantitative results

  - Qualitative evaluation shows benefit of BIER-FRR in comparison to BIFT recomputation

- Evaluation for hardware target showed that packet recirculation occupies significant amount of bandwidth

⇒ Line rate with workaround based on dedicated packet recirculation ports

  - Ports in loopback mode which use port capacity to process recirculated traffic

  - Number of required recirculation ports depend on amount of multicast traffic

► BIER is an efficient transport mechanism for IPMC traffic

- Does not require IPMC-group dependent state in core network

► In case of failures, updating the BIFT takes much time

- Routing underlay restores connectivity faster

► BIER-FRR protects BIER traffic against link and node failures

- BIER packets are tunneled through routing underlay to N(N)Hs
- Leverages resilience or faster reconvergence in routing underlay

► Hardware-based P4 Implementation available

- BIER in line rate
- Quick response time in case of failures