3GPP TSG-RAN WG2 Meeting #113e R2-20xxxxx

Agenda Item: Probably 8.4.3

Source: Qualcomm Incorporated (Email discussion rapporteur)

**Title:** [Post112-e][066][eIAB] Topology Adaptation (QC)

Document for: Discussion

# Introduction

The discussion handles:

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| * [Post112-e][066][eIAB] Topology Adaptation (QC)   Scope: Starting from previous outcomes, centred around the identified / agreed issues, find an agreeable mapping of candidate solution and issue, and analysis of the candidate solution for the issue (e.g. Effectiveness, Gains, Drawbacks). Details also as proposed in [Post112-e][030]. Include at least/Prioritize CHO, type-2/3 RLF indications, local rerouting (and the potential alternatives to those, if any). Intermediate deadlines by Rapporteur.  Intended outcome: Report, collect individual input, in a uniform “format”, and centred around issues, pave the way for meeting discussion and agreement.  Deadline: Long |

The email discussion has two parts.

* **Part 1:** technical discussion on problems/issues that need to be solved, potential enhancements that address these issues, and assessment of efficacy and shortcomings of these enhancements.

**Deadline: December 23rd, 23:59 UTC**.

* **Part 2:** deriving concrete proposals from the technical discussion.

**Deadline: January 12th 11:00 UTC.**

As a reminder, the following agreements have been achieved in TSG RAN2 Meeting #112e:

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| * Consider enhancements to topology adaptation that improve:   + Robustness, e.g., to rapid shadowing,   + service-interruption,   + load balancing among different IAB-nodes, IAB-donor-DUs and IAB-donor-CUs, and   + reduction in signaling load. * RAN2 to discuss enhancements to RLF indication/handling with the focus on the reduction of service interruption after BH RLF. * CHO and potential IAB-specific enhancements of CHO is on the table. * DAPS and potential IAB-specific enhancements of DAPS is not precluded for now (but as there is no PDCP it is not clear how to support DAPS). * For message bundling, RAN2 at least wait for more progress to be made in RAN3 on topology adaptation procedures. * RAN2 to discuss local rerouting, including the benefits over central route determination, and on how topology-wide objectives can be addressed. |

# Phase I: Identification of issues and associated solutions

We consider the following topics with high priority:

* CHO
* Type 2/3 RLF indication
* Local rerouting

Other topics can be discussed with lower priority.

For the first three and potentially further topics, a variety of enhancements has already been discussed before. Further enhancements may be proposed in this discussion. For each enhancement, we want to understand:

1. *What is the technical problem/issue the enhancement aims to resolve?*
2. *How does the enhancement address this issue?*
3. *Assessment of the enhancement with respect to the problem:* 
   1. *How effective is the enhancement in addressing the problem?*
   2. *What are the shortcomings of the enhancement?*
   3. *Are there alternative ways to solve the problem, and how would they work?*
   4. *How much better is the proposed enhancement over these alternatives?*

There may be multiple enhancements proposed for each of the above topics, which need to be separately analyzed.

**Note: This is a technical discussion. There will be no poll. One view may overrule all others, e.g., if it identifies a significant technical problem, or if it provides an elegant solution to an issue considered too complex by everybody else.**

## 2.1 CHO

Rel-16 CHO represents an alternative procedure to Rel-15 Xn-handover and Rel-15 RRC-reestablishment procedures. For IAB, the corresponding *inter-donor* Xn handover and *inter-donor* RRC reestablishment procedures are still under discussion in RAN3. Until RAN3 has made further progress, RAN2 can discuss CHO for *intra*-*donor* IAB-node migration.

Based on prior discussion, there seems to be the notion that Rel-16 CHO can be readily applied to the IAB-MT. It is not clear, however, how Rel-16 CHO would work in conjunction with Rel-16 IAB-node migration, which involves more than the migration of the IAB-MT.

For that reason, the rapporteur proposes the following baseline for IAB CHO, which does *not* require any new signaling messages or IEs. This baseline also addresses concerns raised during prior email discussions on the principal benefits of CHO over RRC reestablishment for IAB.

**Baseline CHO for intra-donor IAB-node migration:**

1) Problem/issue to be addressed: The CU-controlled IAB-node migration procedure may fail when the IAB-MT’s radio link deteriorates very quickly. RLF recovery via RRC Reestablishment is available, but it has rather long interruption time. These problems have been identified for access links in Rel-16, and they equally apply to backhaul links.

2) Enhancement: Combine Rel-16 CHO for IAB-MT with Rel-16 IAB-node migration using off-the-shelf signaling procedures and IEs, in the following manner:

* The IAB-donor performs early preparation of candidate cells on the target IAB-DU for the IAB-MT using the signaling defined for Rel-16 intra-donor IAB-node migration together with CHO-related IEs.
* The IAB-MT is configured with CHO for the target IAB-DU cell including the IAB-related information defined for Rel-16 IAB-node migration as well as all trigger information defined for Rel-16 CHO.
* The IAB-MT’s CHO execution follows the same procedure as defined in Rel-16.
* Configuration of BAP routing, BH RLC channels and DL mapping on the target path to the candidate IAB-DU may occur at the same time as the early preparation of the candidate cells. This is up to CU implementation.
* Migration of UEs and descendent nodes occurs *after* CHO completion as defined for Rel-16 intra-donor IAB-node migration and Rel-16 intra-donor RLF recovery.

3) Assessment of enhancement:

1. Efficacy of enhancement: The interruption time improvement for the BH link is the same as for an access link. The configuration of the backhaul on the target path can be performed early and will not add to the interruption time. Migration of descendent nodes after CHO completion will consume the same time as for Rel-16 IAB-node migration and RLF recovery.
2. Shortcomings: During early preparation, the target DU usually performs reserves resources. For BH, this means that a lot of resources may need to be reserved for BH RLC channels even though BH RLF is a rare event.
3. Alternative solution: RLF recovery via RRC Reestablishment.
4. Delta over alternative solution: Same relative improvement as for access link.

**Q1: Please identify potential problems/issues with this baseline, propose potential enhancements and assess efficacy/shortcomings of these enhancements with respect to the problem/issue identified.**

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| **Company** | **Comment** |
| **Qualcomm** | 1. Problem: During early preparation, the target DU usually reserves resources for the UE. For IAB, this implies that a lot of resources may need to be reserved for BH RLC channels even though BH RLF is a rare event.  2. Enhancement: The target-DU may waive resource reservation for CHO-based preparation.  3. Assessment:   1. Efficacy of enhancement: Addresses the problem. 2. Shortcomings: There may be no resources available when the CHO is executed. This situation, however, is the same when Rel-16 RRC Reestablishment is used instead of CHO. Further, this shortcoming was never considered a serious problem for BH RLF recovery via RRC Reestablishment. 3. Alternative solution: None 4. Delta over altnerative solution: N/A. |
| **Kyocera** | 1. Problem: During the BH RLF at the parent IAB-node (including BH RLF detection, recovering and recovery failure), CHO cannot be triggered at the concerned IAB-node (i.e., child) since CHO Events A3/A5 do not work due to the radio condition between the concerned IAB-node and the parent is still good. In addition, when BH RLF Indication (i.e., Type 4) is received, CHO is still not triggered unless the IAB-node selects a CHO candidate cell.  2. Enhancement: The IAB-node triggers CHO execution when it receives BH RLF Indication (Type 4). FFS if Type 2 in section 2.2 below, if introduced.  3. Assessment:  a) Efficiency of enhancements: Addresses the problem.  b) Shortcomings: There is no shortcoming observed; it’s no harm for the IAB-MT to be handed over to a different cell by CHO, since the IAB-MT will anyway initiate RRC Reestablishment when it receives Type 4 BH RLF Indication, if CHO is not configured. In case Type 2 BH RLF Indication is considered for CHO triggering, we think it needs careful consideration in terms of too aggressive recovery and/or the relationship with local rerouting triggering (if introduced).  c) Alternative solution: RRC Reestablishment  d) Delta over alternative solutions: The donor-controlled BH RLF recovery is provided, e.g., the target cell(s) is deterministic. Also, the interruption time is minimized due to the skip of cell selection process and the prepared resources for CHO as identified in the rapporteur’s summary above. |
| **CATT** | 1.Problem: The UEs and descendant nodes need to perform Rel-16 RLF recovery after CHO completion of the migration node which lead to interruption between migration node and its child nodes. Therefore, service interruption cannot be avoided even though CHO for the migration IAB-node is introduced.  2. Enhancement：Early preparation for descendant IAB-nodes can be considered combined with CHO for the migration IAB node.  3.Assessment：  a) Efficiency of enhancements: Addresses the problem  b) Shortcomings: Resource reservation for child nodes associated with reserved CHO resource for IAB node is considerable.  c) Alternative solution: Child nodes perform RRC Reestablishment procedure after RLF.  d) Delta over alternative solutions: the interruption time is minimized. |
| **Ericsson** | **1. Problem:** RAN2 did not introduce any restriction in Rel.16 to the use of CHO for IAB. According to RRC specification, it is possible to configure an IAB node with CHO, and such node can trigger a CHO upon incurring an RLF and also upon receiving a BH RLF indication from the parent node.  CHO was not introduced in Rel.16 to handle RLF recovery, rather to make the handover more robust. In fact, CHO relies on reserving resources in multiple targets for all the time until the handover is executed by the UE. Since the IAB node is not moving and the only problem that can occur is an RLF, that would imply that the target node would need to keep resources reserved for undefined amount of time, given that the RLF is an unpredictable event. This would then imply a tremendous amount of resource wastage and extra network capacity that an operator would need to plan for.  If it is assumed that the resource reservation may be waived as hinted by QC, then it is not clear how the CHO procedure would work. CHO in fact implies that the UE sends an RRCReconfigurationComplete to the target, not an RRCReestablishmentRequest. If the target has not reserved resources for it how can that work? The IAB node would attach to the target, even though the target has not really admitted yet this IAB node. So the target might eventually release the IAB node, or handover it again. Additionally, the target does not know anything about the IAB node contexts as well as the contexts of the other served IAB nodes and UEs. The context would need to be fetched from the source. So what would be the advantage in the interruption time? What would be the advantage in terms of reduced signaling?  **2. Enhancement: RLF recovery via enhanced RRC Reestablishment (early context fetch)**  The source needs to early prepare the target and inform the target about the UEs/IABs contexts that may be involved in the migration. In this way, at least the target does not need to fetch all the contexts from the source. The IAB node upon selecting this target node for reestablishment, it sends an RRCReestablishmentRequest (not RRCReconfigurationComplete as for CHO). That allows the target to determine whether this IAB node can be admitted or not.  **3. Assessment:**   1. **Efficacy of enhancement:** Reduced interruption time for context fetch, and hence for reestablishment. No need for overdimensioning the capacity of target CU and overprovisioning radio resources, as CHO would imply. 2. **Shortcomings:** Needs potential high amount of signaling to fetch the context and update it. Note however, that such signaling is present also in the CHO-based solution 3. **Delta over CHO:** No need for resource reservation, and overdimensioning target capacity and resources. If resource reservation is assumed to be waived, the CHO solution implies that the IAB node connects to the target CU without being really admitted, since the IAB node sends RRCReconfigurationComplete when CHO is triggered. This can be avoided with the proposed solution. |
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## 2.2 RLF indication/handling

RAN2 agreed to discuss enhancements to RLF indication/handling with the focus on the reduction of service interruption after BH RLF. In prior email discussions, many companies shared the view that type 2/3 RLF indications could reduce service interruption after BH RLF. As a reminder, these indications are defined as:

**Type 2 – “Trying to recover”:** Indication that BH link RLF is detected, and the child IAB-node is attempting to recover from it.

**Type 3 – “BH link recovered”:** Indication that the BH link successfully recovers from RLF.

The following behaviors to type-2 RLF indication were proposed:

* Local rerouting to alternative paths (this will be discussed here, not in local rerouting section),
* Early RLF reestablishment,
* Early measurement of neighboring cells for potential re-establishment
* Trigger of CHO execution (this will be discussed here, not in CHO section)
* Discontinuation/reduction of UL scheduling requests

The prior discussions did not emphasize on the problems/issues the type-2 RLF indication together with any of these behaviors would address, how effective the solution would be and what shortcomings it might have.

The following questions aims to illuminate these aspects for the solutions already proposed. Companies can discuss additional problem/solution scenarios with proper assessment.

**Q2: Please specify potential problems/issues associated with Rel-16 RLF indication (type-4), the potential enhancements to address each of these problems/issues and assess the efficacy/shortcomings of these enhancements with respect to the problem/issue identified.**

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| **Company** | **Comment** |
| Qualcomm 1 | 1) Problem: In Rel-16 IAB, lower tier IAB-nodes underneath an BH RLF point cannot select an alternative UL path they might have since they do not know about the upstream BH RLF.  2) Enhancement: Type 2 indication is used to trigger local rerouting to redundant paths available. The type-2 indication is immediately propagated downstream upon reception so that all descendant nodes can quickly switch to alternative paths.  3) Assessment:   1. Efficacy of solution: Very high since redundant paths can be used to keep BH running. Also, the CU can perform controlled topology adaptation of descendant nodes which is faster than autonomous RLF recovery. 2. Shortcomings of solution: Nothing obvious. 3. Alternative solution: IAB-DU *above* the BH RLF point informs the CU about the RLF. In response, the CU uses the redundant paths to lower tier nodes underneath the RLF point to reconfigure the BH routes. 4. Delta over alternative solution: Both solutions accomplish the same. Type 2 indication may be faster. |
| Qualcomm 2 | 1) Problem: Lower tier IAB-nodes underneath BH RLF point could perform RRC reestablishment as soon as BH RLF has been declared and therefore quickly regain backhaul connectivity, but they do not learn about the BH RLF failure since type-4 indication propagates very slowly.  2) Enhancement: Type 2 indication is used to trigger RRC Reestablishment.  3) Assessment:   1. Efficacy of solution: In case the IAB-node would have to eventually perform RLF recovery, such recovery can be triggered must faster via type-2 than type-4 indication. This implies that the indication is quickly propagated hop-by-hop. 2. Shortcomings of solution: The solution may cause uncontrolled, catastrophic behavior if type-2 indication is flooded across the subtree since all nodes simultaneously try to recover. This may have adverse effects on recovery time. Also, type-3 and type-4 indications would be ineffective since all nodes have already disconnected from their former parents after reception of type-2 indication. 3. Alternative solution: Keep Rel-16 solution based on type-4 indication. 4. Delta over alternative solution: Type-4-triggered RRC Reestablishment is better behaved and should not be replaced by type-2 RRC Reestablishment. |
| Qualcomm 3 | 1) Problem: The IAB-node recovering via RRC Reestablishment may select a former descendent node as the new parent. This should be avoided if the former descendant node does not have BH connectivity, e.g., via an alternative path.  2) Enhancement: The receiving node of type-2 indication mutes IAB-supported indicator in SIB1. To be effective, type-2 indication needs to be immediately forwarded upon reception.  3) Assessment:   1. Efficacy of solution: Works perfectly. 2. Shortcomings of solution: Nothing obvious. 3. Alternative solution: Solutions have been proposed, where the recovering node has detailed topology information of the subtree and can therefore proactively avoid connection attempts at the former descendent. Alternatively, future target cells are preconfigured for each node via CHO. 4. Delta over alternative solution: The alternative solutions are much more complex. The CHO-based solution has several shortcomings. |
| **Kyocera 1** | 1) Problem: During the BH RLF at the parent IAB-node (including BH RLF detection and recovering, i.e., before Type 4 BH RLF Indication), the upstream data cannot reach the donor, i.e., the parent may not send UL grant by flow control or even if the IAB-node (i.e., child) is allowed to transmit, the parent cannot forward the data anyway. The IAB-node cannot perform the local rerouting since it’s not its BH RLF, i.e., the parent’s BH RLF.  2) Enhancement: The IAB-node triggers the local rerouting when it receives Type 2 BH RLF Indication.  3) Assessment:   1. Efficacy of solution: Addresses the problem, if the alternative route is available. 2. Shortcomings of solution: There is no shortcoming observed. We think, however, RAN2 should discuss the overall pictures on relationship of flow control, local rerouting and CHO/RRC Reestablishment, if any. 3. Alternative solution: RRC Reestablishment or CHO triggered by Type 2 BH RLF Indication. 4. Delta over alternative solution: The interruption time can be minimized since the local rerouting is expected to be faster than the alternative solutions. |
| **Kyocera 2** | 1) Problem: During the BH RLF at the parent IAB-node (including BH RLF detection and recovering, i.e., before Type 4 BH RLF Indication), the parent does not send UL grant by flow control. The IAB-node may nevertheless continue sending the scheduling requests, which causes interference.  2) Enhancement: The IAB-node avoids sending SR after it receives Type 2 BH RLF Indication.  3) Assessment:   1. Efficacy of solution: Addresses the problem. 2. Alternative solution: Maybe nothing. 3. Delta over alternative solution: Void. |
| **Ericsson** | 1. **Problem:** Child IAB node is not aware that the parent IAB node has declared RLF or that it is has recovered from an RLF. 2. **Enhancement:** Enabling a parent node to transmit a type-2/type-3 RLF indication to the child. No need to specify child actions. 3. **Assessment:**    1. **Efficacy of solution:** The only thing the child MTs should do is to avoid transmitting data and stop the L2-related timers for retransmissions or discarding data, or triggering failures. This will avoid overflooding of buffers and, in the worst case, losing data if an RLF is really declared. This functionality can be left to the IAB node implementation.    2. **Shortcomings:** No specific drawback, at least if the child actions are left unspecified.   We note however that other actions such as local re-routing, triggering CHO, or RLF triggering are not justified for type-2 for instance. Such actions may end up in ping-pong situations and massive signaling load, for example in case a BH RLF type is then generated. RAN2 needs to remember that IABs carry the load of many UEs, so any massive move of this load will create a huge impact in the network. |
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## 2.3 Local rerouting

Rel-16 supports local rerouting by the IAB-node in the case of BH RLF. R2#112e agreed to discuss local rerouting, including the benefits over central route determination, and on how topology-wide objectives can be addressed.

In prior email discussions, many companies felt that conditions for local rerouting should be relaxed. Not much progress was made on converging on the scenarios where local rerouting would be beneficial.

The following question aims to identify specific problem scenarios for Rel-16 route selection.

**Q3: Please specify problem scenarios for Rel-16 route selection, elaborate on conditions for local route selection that could address these issues, assess efficacy and shortcoming of the solution, and consider potential alternative. Please also discuss how the node can ensure that the locally selected route has no downstream problems.**

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| **Company** | **Comment** |
| Qualcomm | 1) Problem: The egress link of the configure route has high load while alternative routes to the same destination have much lower load (note that this is different from congestion as it may already apply before congestion occurs).  2) Enhancement: The node is allowed to select an alternative link based on the relative load difference between configured route and alternative route. The trigger conditions and the alternative routes may be configured by CU-CP.  3) Assessment:   1. Efficacy: The solution balances the load on the local node. This is certainly helpful if there is only one more BH hop underneath. 2. Shortcomings of enhancement: It is not clear how the local node knows about downstream route conditions. Therefore, the CU-CP should be able to restrict local route selection to a subset of routes where the necessary conditions can be met. 3. Alternative solution: The CU-CP itself reconfigures routes based on load reports. 4. Delta over alternative solution: Small. The CU-CP based reconfiguration may be a little slower, but it may also make better decisions since it has visibility of the available capacity/load on the alternative paths. |
| **Kyocera** | 1) Problem: The IAB-donor is expected to have the topology-wide knowledge, e.g., congestion on a route, and may want to switch a route to an alternative path temporary, or vice versa. Rel-16 mechanism involves a lot of signalling including F1-AP messaging, just for a routing configuration update.  2) Enhancement: The IAB-donor can instruct an IAB-node whether to do the local rerouting.  3) Assessment:   1. Efficacy of solution: Addresses the problem. 2. Alternative solution: Full routing configuration update as in Rel-16. 3. Delta over alternative solution: Signalling load reduction and faster load balancing are expected since the routing configuration does not need to be updated for performing the local rerouting, if alternative path(s) is already included. |
| **CATT** | 1.Problem: R16 IAB-network only consider long-term congestion reduction. When current route is congested, IAB-node can’t switch to available alternative route by local rerouting.  2.Enhancement：R17 IAB support local rerouting triggered by HBH flow control feedback.  3.Assessment：  a) Efficiency of enhancements: Addresses the problem.  b) Shortcomings: It's not globally optimal.  c) Alternative solution: IAB rerouting by the donor CU reconfiguration signaling.  d) Delta over alternative solutions: Improve load balance and resource efficiency in a semi-dynamic and timely way. |
| **Ericsson** | 1. **Problem:** Egress link is becoming congested or IAB node receives a packet with an unknown BAP routing ID (this can happen in case the child has done local rerouting upon RLF declaration in one link) 2. **Enhancement:** The CU configures the IAB node with a signaling that configures the IAB node with rules to perform local routing. RAN2 should discuss such rules, e.g. congestion-based rules.  The CU also configures the rules for selecting an alternative link towards the same destination, e.g. on the basis of radio conditions. 3. **Assessment:**     1. Efficacy: More timely load balancing decision    2. Shortcomings: Decentralizing the routing decision will reduce the ability of the CU to take more accurate decisions when an overload situation occurs. A centralized solution allows to better control the load and configure the network in a way that it can commit to the QoS requirements of the traffic carried by the network. |
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## 2.4 Others

Companies are given the opportunity to discuss other topics in this subsection. The same format should be adhered to as for the topics above.

**Q4: Please specify the problem for a specific topic, elaborate on the solution/enhancement to address this problem, and assess this solution/enhancement with respect to efficacy, shortcoming and how it compares to alternative solutions.**

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| **Company** | **Comment** |
| **Ericsson** | **1. Problem:** Achieve load balancing without massive reconfigurations, with limited signaling overhead, and avoiding ping-pong effects that HO-based load balancing solutions would imply. Overdimensioning the target of CU is also a problem that should be avoided.  **2. Solution:** Dual-protocol stack approaches such as DAPS-like approach or multi-MT.  This solution implies:   * To have a dual protocol stack, i.e. one protocol stack controlled by one CU and a second protocol stack controlled by a second CU for inter-CU case, or both controlled by the donor CU for intra-CU. No need of much coordination between these CUs. * UE/MT contexts can remain in the first CU alleviating the needs of extra resources in a second CU * Only the node subject to load balancing, i.e. IAB node-3 in the figure below, needs to be reconfigured. The served IAB nodes or UEs do not need to be reconfigured. This substantially diminishes the signaling load and increases the robustness of the procedure. * Data is re-routed using rules provided by the CU. * Since both protocol stacks are maintained, there is no service interruption in neither DL or UL.     **3. Assessment:**   1. Efficacy: Avoid massive reconfigurations, limited signaling overhead, no ping-pong effects that HO-based load balancing solutions would imply. No need to overdimension the target. 2. Delta over alternative solutions: This solution is superior to CHO or any discussed so far e.g. Dual Connectivity, see efficacy analysis above. It hence fulfills all goals of this WI and has minimum standardization impact 3. Shortcomings: In case a DAPS-like solution is adopted, a specific “dual IAB protocol stack” (DIPS) terminology needs to be introduced to avoid confusion with the legacy DAPS. The legacy DAPS is based on PDCP. The DIPS is based on dual BH RLC channels operations. One BH RLC channel used for communication with one parent, and the second BH RLC channel with the other parent. Note also that for the load balancing use case, there seems to be no need to introduce reordering/discarding functionality at the BAP layer as it is in PDCP. |
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# 3 Phase II: Agreeable mappings of issues/solutions

To be filled later.

# 4 Conclusion

To be filled later.