**3GPP TSG-RAN WG4 Meeting # 98-bis-e R4-210XXXX**

**Electronic Meeting, 12th – 20th April, 2021**

**Agenda item:** 8.16

**Source:** Moderator (Huawei, HiSilicon)

**Title:** Email discussion summary for [98-bis-e][140] NR\_cov\_enh

**Document for:** Information

# Introduction

This email thread discusses the phase continuity and power consistency across PUSCH/PUCCH repetition for NR coverage enhancements WI in AI 8.16, including the following sub-topics:

* Sub-topic 1-1: Conditions to keep phase continuity and power consistency
* Sub-topic 1-2: Phase continuity tolerance

Note: R4-2104702 submitted to AI 12.1 is also discussed in this thread.

List of candidate target of email discussion for 1st round and 2nd round:

* 1st round: Invite companies to review the recommended WF and provide comments directly under each issue in section 1.2.1 and 1.2.2.
* 2nd round: prepare the WF and additional reply LS to RAN1.

# Topic #1: Phase continuity and power consistency for PUSCH and PUCCH repetition

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [R4-2104580](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2104580.zip) | MediaTek inc. | Observation 1. In order to maintain phase continuity during those unscheduled symbols between UL repetition, UE power consumption would get higher and the OFF power requirement cannot be met.  Proposal 1: RAN4 to deprioritize the non-back-2-back UL repetition scenario.  Observation 2: SRS typically has very different settings on antenna port, occupied PRBs and UL power to PUCCH and PUSCH. It is an extreme corner case to see all these settings are exactly the same between SRS and PUSCH/PUCCH.  Proposal 2: RAN4 does not consider the scenario of other physical signals/channels in-between PUCCH or PUSCH repetitions in later study on phase continuity and power consistency.  Observation 3: The use case to remain phase continuity and power consistency for UL repetition is not clear under CA scenario.  Proposal 3: RAN4 to further check the use case and the necessity to consider phase continuity and power consistency for UL repetition under CA scenario.  Proposal 4: RAN4 to further check the use case and the necessity to consider phase continuity and power consistency for UL repetition under DC scenario. |
| [R4-2104955](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2104955.zip) | China Telecom | Observation 1: Potential use cases for joint channel estimation with non-zero gap in-between adjacent transmissions have been identified in RAN1.  Observation 2: Non-back-to-back PUSCH transmissions within one slot or across slots can happen in several practical scenarios.  Observation 3: Based on LTE experience, it is feasible to consider non-zero gap between uplink transmissions with joint channel estimation.  Proposal: RAN4 to confirm the feasibility to keep phase continuity and power consistency (with certain tolerance level) for scenario with non-zero gap in-between the PUSCH or PUCCH repetition, and further discuss the possible number of OFDM symbols for the gap. |
| [R4-2106918](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2106918.zip) | InterDigital Communications | Observation 1: The PT-RS may help mitigate the phase continuity during non-contiguous repetitions and UE based phase drifting.  Observation 2: The DM-RS symbol can be delayed during the repetition’s slots allowing for phase shift evaluation against the first repetition that contain the phase reference PT-RS.  Observation 3: The DM-RS symbol can be delayed during the repetition’s slots allowing for phase shift evaluation against the first repetition that contain the phase reference PT-RS.  Proposal: Study the phase continuity for non-contiguous and contiguous transmissions and implementation phase drift issues in the context of mitigations methods like PT-RS insertion for FR1 and FR2. |
| [R4-2107273](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2107273.zip) | Huawei,HiSilicon | Proposal 1 : For case that un-scheduled UL symbols between 2 UL transmissions, phase continuity can be maintained, which requires for off power exception on the unscheduled symbol(s).  Proposal 2: if there is one slot un-scheduled between 2 UL tranmission, phase continuity cannot be maintained. |
| [R4-2107284](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2107284.zip) | Qualcomm Incorporated | withdrawn |
| [R4-2107366](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2107366.zip) | Qualcomm Incorporated | We discussed the two cases left open in the LS: Case of un scheduled symbols between repetitions and the case of other UL channels between repetitions and made three proposals.  Proposal 1: The gap when there is no other channel band in between two repetition can be up to 14 symbols.  Proposal 2: In the case of different channel in between two repetitions, a guard period before returning to the repetitions is defined. Length of guard period is Y is FFS.  Proposal 3: The length including the guard period of the other channel in between two repetitions is less than 14 symbols.  We also discussed about the amount of phase shift when phase can be contiguous and since receiver evalautionm was excluded in the work, we made one proposal:  Proposal 4: The amount of phase change allowed for the UE when phase between two repetitions is considered to be contiguous shall be less than 160 degrees |
| [R4-2104702](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_98bis_e/Docs/R4-2104702.zip) | Sony | In this contribution we have discussed phase continuity for PUCCH and PUSCH repetition and UE configuration for enhanced Joint Channel Estimation in TDD. The following observations and proposal are made:  Observation 1 It is important to have non-zero X un-scheduled UL OFDM symbols in-between the PUSCH and PUCCH repetition to make the JCE more useful in practical scenarios.  Observation 2 Phase continuity can be maintained if off power is not required on the un-scheduled symbols by remaining the Tx chain state unchanged.  Observation 3 For UEs with cross switch, i.e. UEs that have multiple Rx/Tx chains, it is possible to use different antennas for UL and DL traffic during the JCE window.  Observation 4 For FR2 a UE needs to be able to request an alternative beam for DL.  Observation 5 Companies are encouraged to estimate the required tolerance of the phase continuity and amplitude consistency needed for JCE.  Proposal 1 Companies are encouraged to investigate the additional power needed to keep the PA biased during the DL periods.  Proposal 2 Companies are encouraged to investigate the required isolation between the antenna ports to avoid desensitization from PA noise leakage.  Proposal 3 Companies are encouraged to investigate the risk of having too weak signal at the second antenna.  Proposal 4 UE capability of supporting JCE and signaling that JCE is not applicable is needed. |

## Open issues summary

### Sub-topic 1-1: Conditions to keep phase continuity and power consistency

**Issue 1-1-1: Non-zero un-scheduled gap**

Issue description: Whether it is feasible to keep phase continuity and power consistency when there is non-zero un-scheduled UL OFDM symbols in-between the PUSCH and PUCCH repetition:

* Proposals
  + Option 1: Feasible (China Telecom, Huawei, Qualcomm, Sony)
    - Huawei: PLL, RFIC and PA do not switch off, and off power exception on the unscheduled symbol(s).
    - Qualcomm: UE can leave the transmitter in to ON state and only ramp down the signal chain
    - Sony: Phase continuity can be maintained if off power is not required on the un-scheduled symbols by remaining the Tx chain state unchanged.
    - China Telecom: Potential use cases have been identified in RAN1 and seen in practical scenario; feasible to consider non-zero gap based on LTE experience.
  + Option 2: Deprioritize non-zero gap scenario (MediaTek)
    - MediaTek: UE power consumption would get higher and the OFF power requirement cannot be met.
* Recommended WF
  + Based on majority’s view, is it possible to firstly confirm the feasibility in general, and further discuss the exact number of OFDM symbols in Issue 1-1-1A?

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | We support to agree on option 1 and send the information to RAN1 in this meeting.  To our knowledge, RAN1 is waiting for RAN4 feedback on non-zero un-scheduled gap scenarios. |
| Qualcomm | Agree w Option1., Should discuss exact wording asap |
| InterDigital | Support Option 1, but the phase continuity mitigation methods like PT-RS insertion can be added here. |
| MTK | We have concern on non-B2B case.  At least it is not feasible if RAN4 does not revise the off power requirement.  We do not understand why network would choose to use non-B2B scheduling to keep UE power wasting rather than B2B scheduling. We would like to hear more justification from companies. |
| Huawei, HiSilicon | We support option 1, whether off power can be met on the unscheduled symbols need further study in RAN4. In our understanding, there could be power exceed off power if RF component is maintained with on. |
| Sony | We support option 1. |
| Ericsson | Option 2. We have same concern with MTK, the ON-OFF mask apply between the ON power symbols and unscheduled symbol (OFF power). We think before we agree on the feasible of the Issue 1-1-1, we need investigate the network impact if such UE can have exception of the ON-OFF mask as several companies concerns that UE could exceed off power |

**Issue 1-1-1A: Length of un-scheduled gap for Issue 1-1-1**

* Proposals
  + Option 1: Less than 14 OFDM symbols (Huawei)
  + Option 2: Up to 14 OFDM symbols (Qualcomm)
* Recommended WF
  + It seems the only difference between the two options is whether 14 OFDM symbols can be considered. Further discussion and views from more companies are encouraged.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | Pending on the conclusion in Issue 1-1-1 |
| Huawei | We support option 1. |
| Qualcomm | Options are almost the same. Pls not that we are proposing to have a guard in the gap so this depend on the definition of the gap, see issue 1-1-2. |
| Ericsson | Depend on issue 1-1-1. |

**Issue 1-1-2: Non-zero gap with other signals/channels for the UE**

Issue description: Whether it is feasible to keep phase continuity and power consistency for scenarios of other physical signals/channels in-between PUCCH or PUSCH repetitions from the UE perspective, e.g., SRS or PUCCH transmission in-between the PUSCH repetition for the UE.

* Proposals
  + Option 1: Not consider these scenarios (MediaTek)
    - MediaTek: SRS typically has very different settings on antenna port, occupied PRBs and UL power to PUCCH and PUSCH.
  + Option 2: A guard period before returning to the repetitions should be defined, and the length including the guard period of the other channel in between two repetitions is less than 14 symbols. (Qualcomm)
* Recommended WF
  + Encourage more inputs

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | If the other signals/channels to be scheduled during the non-zero gap have exactly the same setting in antenna port, occupied PRBs, UL power, … to the repeated transmission signals/channels, then it probably can be feasible. But to our understanding the chance to meet this condition is extremely low. We are not sure if RAN4 needs to spend time on the corresponding requirement. |
| Huawei, HiSilicon | For option 2, we have questions: whether guard period is for transient period of power change? Do we have limitation on DMRS position for this case? We have concern on how accurate phase can be maintained by guard.  However, we agree with MTK that, with other physical channel transmit between repetitions, if the power, RB, port, conditions that we define for phase continuous transmission can be met, then phase can be maintained. |
| Sony | We think it is important to support scenarios of allowing other physical channels in between PUCCH or PUSCH repetition to enlarge the usage scenario of the joint channel estimation. According to the contributions in this meeting, this is seeming a feasible solution with at least a guard period as proposed in Option 2.  As MTK and Huawei have pointed out, it is important that conditions for phase/amplitude continuous transmission can be met. Considering RAN4 has not concluded on the condition (amplitude and phase drift that network can tolerate for joint channel estimation), we don’t think those possible scenarios can be precluded. |
| Qualcomm | Just to note that the case is that repetition PUSCH/PUCCH power would be the same but the channel in between repetition can be different. |

**Issue 1-1-3: PUCCH/PUSCH repetition under CA and DC scenarios**

Agreements related to CA/DC in RAN4 #98e (Approved reply LS in R4-2103393):

* *Question 1: Under what conditions UE can keep phase continuity cross PUCCH or PUSCH repetitions*
* *RAN4 Answer for question 1: If the following conditions are met*
  + *…*
  + *No change on transmission power level of its own CC, i.e., no change on the power control parameters specified in TS 38.213, and also when own CC is not impacted by other concurrent CC(s) that are configured for inter-band CA or DC for same UE with dynamic power sharing and no change in any configured CC s that are part of configured intra-band uplink CA or DC.*
  + *…*
* Proposals
  + Option 1: RAN4 to further check the use case and the necessity to consider phase continuity and power consistency for UL repetition under CA and DC scenarios. (MediaTek)
* Recommended WF
  + Keep the RAN4 agreements in the reply LS approved in the last meeting, and leave the decision on the applicable use cases to RAN1.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | Support the recommended WF from moderator. No need to send additional information on CA/DC scenario to RAN1. |
| MTK | Just for clarification. We are not proposing to revert any RAN4 agreements in last meeting. We are fine with the agreement and leave it for RAN1 to carry on their discussions.  The purpose of the proposal is whether in RAN4 we need to define requirement for CA and DC scenario. Sorry for any mis-understanding. The reason is that in power hungry scenario where we need this coverage enhancement mechanism, we believe it is a better strategy to allow all UE power on one single CC rather than distribute them into multiple CCs. |
| Qualcomm | Would leave this to RAN1. Agree with recommended WF |

**Issue 1-1-4: Phase drift mitigation methods like PT-RS insertion for FR1 and FR2**

* Proposals
  + Option 1: Study the phase continuity for non-contiguous and contiguous transmissions and implementation phase drift issues in the context of mitigations methods like PT-RS insertion for FR1 and FR2. (InterDigital)
    - Observation 1: The PT-RS may help mitigate the phase continuity during non-contiguous repetitions and UE based phase drifting.
    - Observation 2: The DM-RS symbol can be delayed during the repetition’s slots allowing for phase shift evaluation against the first repetition that contain the phase reference PT-RS.
    - Observation 3: The DM-RS symbol can be delayed during the repetition’s slots allowing for phase shift evaluation against the first repetition that contain the phase reference PT-RS.
* Recommended WF
  + Encourage feedback

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | One issue is that it seems typically PT-RS will be not configured / used in FR1 and FR2 QPSK scenarios. |
| Qualcomm | This would be RAN1 discussion. If PT-RS is assumed or not. RAN4 can agree different values, relaxed phase continuity requirements w PT-RS than w/o PT-RS but some studies are needed. |
| InterDigital | To answer China Telecom’s comment:  Indeed, PT-RS currently is not used in FR1 and it is optional to be configured along DM-RS in FR2. In this paper we are proposing to use PT-RS as a mitigation method for phase continuity at the gNB receiver.  This will eventually enable a gNB phase correction for non-contiguous repetitions or certain interrupted transmissions by unscheduled symbols or gaps.  If we agree study the phase continuity with and without PT-RS, at least we will know the impact. |
| MTK | Leave this to RAN1 |
| Huawei, HiSilicon | We may get the gain from joint channel evaluation and reduce the DMRS number, but if we add PTRS to get phase contiguous, what would be the gain compared with current channel evaluation method? |

**Issue 1-1-5: DL slot(s) in-between repetition**

Issue description: Whether it is feasible to keep phase continuity and power consistency for scenarios with DL slot(s) in-between PUCCH or PUSCH repetition in the same band for TDD case

* Proposals
  + Option 1: Use different antennas/panels for UL and DL traffic during the JCE window (Sony)
    - Separate UL / DL antennas in FR1
      * Companies are encouraged to investigate the additional power needed to keep the PA biased during the DL periods.
      * Companies are encouraged to investigate the required isolation between the antenna ports to avoid desensitization from PA noise leakage.
      * Companies are encouraged to investigate the risk of having too weak signal at the second antenna.
      * UE capability of supporting JCE and signaling that JCE is not applicable is needed.
    - Separate UL/DL panels in FR2
      * For FR2 a UE needs to be able to request an alternative beam for DL.
* Recommended WF
  + Encourage feedback

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Huawei, HiSilicon | For TDD case, we think it is not possible to maintain the phase when DL in-between repetition. |
| Sony | It was concluded in the last RAN4 meeting that “No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case” to maintain the phase/amplitude continuity. Though this might be true in general, we see some possible implementations that can maintain the TX chain untouched while having the RX reception. For example, a UE can keep Tx on while the antenna can switch to Rx as long as there is good isolation in between. This can be introduced as an optional feature for certain UEs who support such an implementation.  To enlarge the possible usage of the joint channel estimation, we recommend further study on this issue. |
|  |  |

### Sub-topic 1-2: Phase continuity tolerance

**Issue 1-2-1: Amount of phase change from UE implementation aspect**

* Proposals
  + Option 1 (Qualcomm):The amount of phase change allowed for the UE when phase between two repetitions is considered to be contiguous shall be less than 160 degrees.
    - Repetitions are assumed to be for coverage enhancement and lowest MCS is assumed to be use
    - The number may seem excessive but from UE design point of view without know what matters to the receiver, this is what is desirable with the current knowledge.
    - If the feature is applicable for MIMO, TX switching, CA should be discussed separately after baseline is consensus is achieved for one TX cases.
* Recommended WF
  + Encourage more inputs

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | We also think that the proposed number may seem excessive. More discussion is needed. |
| InterDigital | More discussions are needed. |
| MTK | We need infra vendors to tell us how good is good enough to achieve gain in UL reception performance. |
| Huawei, HiSilicon | The key problem is not how much tolerance UE can meet, it is how much tolerance for gNB side can support the joint evaluation. |
| Sony | We agree it is important to look into the UE design point of view. However, it is not sufficient for RAN4 to define the requirement accordingly. We think it is necessary to understand how much phase and amplitude continuity the network can tolerate to perform the joint channel estimation. |

**Issue 1-2-2: Quantification of the acceptable/required tolerance**

* Proposals
  + Option 1: To estimate the required tolerance of the phase continuity and amplitude consistency from link performance perspective (Sony, [QC])
    - Sony: It is important to clarify the scenario for the UL JCE so that RAN4 (and RAN1) can quantify the acceptable tolerance of phase continuity and amplitude consistency.
    - QC: The intent is to enable phase continuity in the receiver or the repeated transmissions. RAN4 can further discuss further tightening of the phase change value but so far there is no knowledge why that would be needed.
* Recommended WF
  + Encourage more feedback

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | Support to estimate the required tolerance of the phase continuity and amplitude consistency from link performance perspective, which is important input to conclude Issue 1-2-1. |
| InterDigital | Support the evaluation and we suggest adding PT-RS to the study as a mitigation method for phase continuity problematic scenarios. |
| MTK | Support to have some evaluation in order to know the tolerance |
| Huawei, HiSilicon | We support to have some evaluation by LLS. |
| Sony | We support evaluation. We think it is necessary to understand how much phase and amplitude continuity the network can tolerate if RAN4 would define the requirement on it.  It is not sufficient to only analyze it from the UE implementation aspect if the RAN4 requirement should make sure the network can actually perform the joint channel estimation. |
| Qualcomm | Support the evaluation on link level. |
| Ericsson | We are ok with the LLS. The simulation assumption however needs to be agreed and we assume this can be discussed in the first WID meeting in May. |

## Companies views’ collection for 1st round

*Provided under each issue in section 1.2*

## Summary for 1st round

### Open issues

*Moderator tries to summarize discussion status for 1st round, list all the identified open issues and tentative agreements or candidate options and suggestion for 2nd round i.e. WF assignment.*

|  |  |
| --- | --- |
|  | **Status summary** |
| **Sub-topic#1-1** | **Issue 1-1-1: Non-zero un-scheduled gap**  5 companies confirm the feasibility of phase continuity for **Non-zero un-scheduled gap**  2 companies have concern on: whether UE can meet off power requirement during the un-scheduled gap.  Tentative agreement:  RAN4 confirm the feasibility of phase continuity for Non-zero un-scheduled gap case at least when UE is not required to meet off power requirement during the un-scheduled gap  *Recommendations for 2nd round:*  Further discuss on the concerns, capture the discussion outcome in the reply LS.  **Issue 1-1-1A: Length of un-scheduled gap for Issue 1-1-1**  *Recommendations for 2nd round:*  More input in the 2nd round, capture the discussion outcome in the reply LS.  **Issue 1-1-2: Non-zero gap with other signals/channels for the UE**  Tentative agreement:  If the other signals/channels to be scheduled during the non-zero gap have exactly the same setting in antenna port, occupied PRBs, UL power, … to the repeated transmission signals/channels, it is feasible to maintain the phase across the repetitions.  *Recommendations for 2nd round:*  The solution with guard period to maintain phase across repetitions may need more discussion, capture the discussion outcome in the WF if there is.  If there is agreement on feasibility agreement on Non-zero gap with other signals/channels case, capture the outcome in the reply LS.  **Issue 1-1-3: PUCCH/PUSCH repetition under CA and DC scenarios**  *Recommendations for 2nd round:*  With explanation from MTK, we could further discuss whether RAN4 need to check the use case and the necessity under CA and DC scenarios. capture the discussion outcome in the WF if there is.  **Issue 1-1-4: Phase drift mitigation methods like PT-RS insertion for FR1 and FR2**  *Recommendations for 2nd round:*  Further discuss on necessity to study on phase drift mitigation by inserting PTRS in RAN4, capture the discussion outcome in the WF if there is.  **Issue 1-1-5: DL slot(s) in-between repetition**  *Recommendations for 2nd round:*  More input is recommended in 2nd round, capture the discussion outcome in the WF if there is.  **Issue 1-2-1: Amount of phase change from UE implementation aspect**  *Recommendations for 2nd round:*  More input is recommended in 2nd round, capture the discussion outcome in the WF if there is.  **Issue 1-2-2: Quantification of the acceptable/required tolerance**  Tentative agreement:  RAN4 to estimate the required tolerance of the phase continuity and amplitude consistency from link performance perspective.  *Recommendations for 2nd round:*  Further discuss on the simulation assumption consideration from Ericsson in the 2nd round, capture the discussion outcome in the WF. |

*Suggestion on WF/LS assignment*

|  |  |  |
| --- | --- | --- |
|  | **WF/LS t-doc Title** | **Assigned Company,**  **WF or LS lead** |
| #1 | Reply LS on PUCCH and PUSCH repetition | Qualcomm Incorporated |
| #2 | WF on phase continuity and power consistency for PUCCH and PUSCH repetition | Huawei, HiSilicon |

## Discussion on 2nd round

1. Recommendations for Tdocs
   1. 1st round

**New tdocs**

|  |  |  |
| --- | --- | --- |
| **Title** | **Source** | **Comments** |
| WF on … | YYY |  |
| LS on … | ZZZ | To: RAN\_X; Cc: RAN\_Y |
|  |  |  |

**Existing tdocs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics incl. existing and new tdocs.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. For new LS documents, please include information on To/Cc WGs in the comments column
4. Do not include hyper-links in the documents
   1. 2nd round

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
| R4-210xxxx | WF on … | YYY | Agreeable, Revised, Noted |  |
| R4-210xxxx | LS on … | ZZZ | Agreeable, Revised, Noted |  |
|  |  |  |  |  |

Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. Do not include hyper-links in the documents