3GPP TSG-RAN WG1 Meeting #97 Tdoc R1-19xxxxx

Reno, USA, May 13th –17th, 2019

Agenda Item: x.x.x

Source: Ericsson

Title: Summary of email discussion on indoor industrial channel model and calibration

Document for: Information

# 1 Introduction

The purpose of the present tdoc is to summarize the email discussion [97-NR-10] Channel model and calibration.

[97-NR-10]

Email discussion/approval using the tables in R1-1907758 as a starting point for additional modeling of IIIoT and to converge on calibration assumptions until 7/12, followed by calibration results till next meeting – Henrik (Ericsson)

The complete set of agreements in the indoor industrial channel model SI [1], up to and including RAN1#97, is available in [2]. A text proposal in the form of a draft CR to TR 38.901 that implements these agreements is available in [3]. The present email discussion builds on these agreements.

The email discussion will use the following scope and timeline.

For the model agreement:

1. Collect company input until **June 20**:
   1. Path loss
      1. As per agreement from Reno, companies are encouraged to share raw path loss data via the channel model reflector
      2. As per agreement from Reno, companies are encouraged to share path loss model parameters using the excel file as in R1-1907405
   2. LOS probability
   3. Fast fading
      1. As per agreement from Reno, collect LSP proposals from all companies using the excel file in R1-1907407 as the template
   4. Other model details including scenario description and additional model components
2. Merge inputs until **July 5**
   1. Using methods for merging agreed in Reno, potentially with additional details on the merging discussed and agreed
3. Summarize the merged inputs and approve these as tentative model settings (e.g. within square brackets) until **July 12**

For the model calibration:

1. Collect company input on calibration assumptions including metrics, until **June 14**
2. Agree on calibration assumptions including metrics, until **July 12**
3. Perform calibration using the tentative model settings and collect companies’ calibration results, until **Aug 18**

# 2 Company input

In the first phase of the email discussion companies are invited to give their input on various aspects of the indoor industrial channel model as specified in the subsections below.

## 2.1 Path loss

The following agreements with relevance to the path loss modeling were reached at RAN1#97:

Agreements**:**

Specify an additional penetration loss for devices embedded in machinery or enclosures

* FFS on details, including material and frequency dependence
* FFS on impact on LOS probability and fast fading

Agreements**:**

Merge path loss models per sub-scenario

* Perform multi-dimensional regression as a starting point
  + FFS on weighting of results from different sources
* For the merging:
  + Collect raw data (distance, power, f, antenna height, sub-scenario) from companies. Companies are encouraged to share the raw data via the channel model reflector
  + Generate random variables from different path loss models where the raw data is not available, taking care to use similar number of samples as used to fit the reported model. Companies are encouraged to share model parameters using the excel file as in R1-1907405
  + Fit the path loss and shadow fading using the combined raw data and generated random data

Agreements**:**

Derive a common LOS path loss model for all industrial sub-scenarios

Agreements:

Use the ABG or CI path loss model

* Frequency-dependence on the A and B parameters in the ABG model is FFS

In line with the above agreements, companies are encouraged to share path loss model parameters or raw path loss data (if available) along with their views on the remaining details of path loss modeling by providing their views below.

**P1: Please provide path loss model parameters using the attached excel file, which is based on the excel file in R1-1907405 [4]. Further comments or information on the shared parameters can be detailed below**

|  |  |
| --- | --- |
| **Company** | **Comments on path loss model parameters** |
| Ericson | We have extracted path loss model parameters from some of the published references in our literature survey in R1-1813129 and added these to the excel file “Path loss model parameters\_v2.xlsx”. |
| Nokia | We have extracted all available path loss model parameters from our reported literature since RAN1#94-bis. They are merged with the Ericsson ones in the attached excel file “Path loss model parameters\_v2\_nokia.xlsx”. |
| ZTE | We have extracted path loss model parameters from our contributions and merged into the attached excel file :“Path loss model parameters\_v2\_nokia\_zte.xlsx”. |
| Qualcomm | We have added parameters/observations from the results of measurements described in R1-1907300 on the additional path loss due to device embedding in the attached Excel File: :“Path loss model parameters\_v2\_nokia\_zte\_qc.xlsx”. |
| Fraunhofer IIS | We will add parameters/observations from measurements results on the path loss soon. We are right now analyzing the measurement data and preparing a tdoc, which we will share using the channel model reflector. |
| CMCC | We have extracted path loss model parameters of 4.9GHz (from R1-1904742) and 28GHz and merged into the attached excel file : “Path loss model parameters\_v2\_nokia\_zte\_qc\_FHG\_CMCC(v2)\_DCM.xlsx” in row 84 and 86. |
| NTT DOCOMO | We have extracted path loss model parameters from our contributions in R1-1906231 and merged into the attached excel file : “Path loss model parameters\_v2\_nokia\_zte\_qc\_FHG\_CMCC\_DCM.xlsx” |
| Huawei | We have extracted path loss model parameters. They are merged into the Excel file, and submitted to the 3GPP RAN1 reflector on 8th May, 2019. We also plan to do some new measurement based on process of 3GPP discussion. |
| Fraunhofer IIS | We have extracted PL parameters for the CI model in LOS and NLOS with TX below and above clutter level from ultra-wideband measurements between 4.75 GHz - 8.75 GHz. |

**P2: Please share raw path loss data (if available) e.g. using the channel model reflector or by referencing previous contributions. Further comments or information on the shared raw data can be detailed below**

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| --- | --- |
| **Company** | **Comments on raw path loss data** |
| Ericsson | At present we do not have any raw path loss data available, but we are making an attempt to gather such data. If successful, we may share such data using the channel model reflector. |
| Nokia | We have shared a huge amount of 3.5 GHz and 28 GHz raw measurement data in R1-1906662, RAN1#97, which also includes a summary of the parametrizations. |
| ZTE | The path loss figures of raw data are available in appendix 1~7 in R1-1904227, but due to the data amount is too huge, we prefer to provide model parameters as in “Path loss model parameters\_v2\_nokia\_zte.xlsx”. |
| Qualcomm | We also are in the process of gathering additional data and may share later. |
| Fraunhofer IIS | We are right now analyzing measurement data and preparing a tdoc, which we will share using the channel model reflector. Data will be shared later. |
| CMCC | The raw data of 4.9GHz path loss in R1-1904742 will be shared in the channel model reflector.  The 28GHz raw data has also been shared in the channel model reflector. |
| NTT DOCOMO | We attached raw data in this compressed folder. File name is "Pathloss\_rawdata\_DOCOMO.xlsx" which is same raw data of measurement results explained in R1-1906231. |
| Huawei | We have already shared the previous measurement raw data in the Excel file PathlossSummary\_r2.xlsx on 8th May 2019. |
| Fraunhofer IIS | We have included path-loss model parameters in the table “Path loss model parameters\_v2\_nokia\_zte\_qc\_FHG.xlsx” and the description of the measurements and results in “R1-XXXX-Single-band.doc”. |

**P3: Please provide views on further details of the data merging**

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| **Company** | **Views on path loss data merging** | **Proposals** |
| Ericsson | Any “reasonable” approach to merging may be fine, e.g. equal weight per measurement campaign or equal weight per sample could be acceptable. |  |
| Nokia | Quantity and quality of the available path loss data should be considered when blending the data to fit a model. If raw measurement data samples are not available (i.e. from literature studies), path loss results could be reconstructed by generating clouds of points with similar characteristics to those in the study by considering the exact number of samples over the full measurement distance range (if available) or an approximate number of samples estimated visually from some of the plots. Measurements performed over large measurement distance ranges (i.e. spanning over more than 2 (or at least close to 2) distance decades, 1-100 m should be more valid than others spanning over shorter distance ranges) as they ensure a more reliable path loss exponent estimation. |  |
| ZTE | Any “reasonable” approach to merging is fine while equal weight per source shall be considered. |  |
| Qualcomm | In our opinion, elaborate weighing mechanism can be counter-productive. A simpler approach where the inclusion of a data set is done based on agreed-upon minimum requirements, e.g., sample size and completeness of specified fields, and thereafter have equal weightage among those included |  |
| CMCC | Any “reasonable” approach to merging is fine.  We should be careful not to let one measurement campaign with massive data samples to overwhelm the trends of the other campaigns. Statistical model should cover and present multiple scenarios’ characteristic, not only one scenario. |  |
| NTT DOCOMO | Validity of the measurement or path loss model should be investigated carefully, but “reasonable” approach to merging these validated data is acceptable such as equal weight. |  |
| Huawei | Compared to literature review, raw measuring data is preferred. That will be easier to merge measurement results. Measurement report should have sufficient information about the environment (sub-scenario, clutter type, room size, etc.). Other useful literature results are not excluded, but need to make sure the information is sufficient (including the key parameters such as distance, frequency, standard deviation) to reconstruct the data which is been used for path loss merging. |  |
| Fraunhofer IIS | Any reasonable method would be accepted, considering the large variety of scenarios that have been presented. However, influence of the different measurement equipment characteristics (antennas, bandwidth, etc.) on the resulting parameters must be further investigated. |  |

**P4: Please provide input on the additional path loss for embedded devices and the impact on LOS probability and fast fading**

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| **Company** | **Views on additional loss for embedded devices** | **Proposals** |
| Ericsson | It should be sufficient to specify a fixed value or a range for the penetration loss. To avoid making the model overly complex it is preferable if the LOS probability and fast fading parameters are kept the same as for devices that are not embedded. The interpretation of LOS for an embedded device is then that there is LOS to the enclosure, similar to the way we use LOS for indoor users in the UMa and UMi scenarios.  Some machine enclosures use windows of plexiglass. If we assume that the plexiglass is basically lossless at the RF frequencies of interest, the net effective loss can be determined from the fraction of enclosure area that consists of windows, e.g. 50% = 3 dB, 25% = 6 dB, 10% = 10 dB, etc. This simple model should be validated against the available measurements. | * Keep the modeling of “embedded devices” simple by only specifying a value or a range for the additional path loss experience by embedded devices * Determine the enclosure loss as the inverse of the fraction of the enclosure area that consists of plexiglass windows, e.g. 50% = 3 dB, 25% = 6 dB, 10% = 10 dB, etc   + Note: This simple model should be validated against measurements |
| Nokia | We share the same view as the above from Ericsson. A simple embedded device loss should be considered in order to keep the model simple. The LOS probability and fast fading should be those of the “ray” path travelling through the clutter from the source to the outer part of the device. | * Keep the modeling of “embedded devices” simple by only specifying a value or a range for the additional path loss experience by embedded devices. * Penetration loss values should come from empirical evidences as those reported by Qualcomm. |
| ZTE | We prefer a simple model to enclosure, e.g. a range of penetration loss. |  |
| Qualcomm | In our view, for embedded devices, there will be strong dependence of the additional path loss on the enclosure material type, as well as the operating frequency (as discussed in R1-1907300). While many enclosures do have sizable plexiglass windows, there are others, e.g., enclosures for motors, which are known not to be so. Hence, the range of the additional path loss due to device embedding should account for such scenarios as well.  Given the high-reliability requirement in industrial use-cases, we think more careful consideration should be given for the need to model the impact of device embedding on other channel parameters, including LoS probability and small-scale parameters. | * Consider modeling additional pathloss due to device embedding that depends at least on the material of the enclosure and the operating frequency. * Consider the impact of device embedding on other channel-model parameters, including LoS probability and small-scale parameters |
| NTT DOCOMO | We think we should add fixed value to path loss for embedded device. Fast fading parameter can be same for this case. | Define fixed value added to path loss for embedded device.  Use same fast fading parameter for embedded device from not embedded case. |
| Huawei | A certain distribution, e.g. log-normal may be sufficient to model this additional loss. Will treat it as additional large scale loss, and will not influence other small scale fading. | * Additional penetration loss with log-normal distribution can be considered, deviation value can be decided by literature review or additional measurement campaign. |

**P5: Please provide input on any other aspects of path loss modeling**

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| **Company** | **Views** | **Proposals** |
| Nokia | Given the scarce amount of data available to perform the fittings for the different sub-scenarios, we foresee that the CI model will provide more stability to the model, allowing a clearer distinction between clutter types and antenna configurations than the one achievable with the ABG model. In case the modeling become tedious due to the different nature of the data for different frequency bands, we recommend considering the modeling approach with simple free-space frequency scaling proposed in contributions R1-1810659, R1-1813177, R1-1904824 with appropriate parametrization. | * In case ABG model does not provide the adequate level of consistency across expected trends in the different sub-scenarios, CI model should be considered. |
| ZTE | 1. We prefer CI model as well. 2. Besides 20\*log10(fc), frequency-dependent slope is observed in our simulation as well | * CI model is preferred. * Frequency-dependent slope shall be considered as well. |
| CMCC | 1, ABG model is preferred.  Since we have a long discussion about ABG and CI model for 38900/901, and the final conclusion is that the ABG is used for the NLOS case, CI model is optional. It is preferred to align with that conclusion.  CI model may be suitable for the LOS case since it is similar to the free space. But it is not physically reasonable to use CI model for NLOS case, since there are always obstacles between the transmitter and receiver, the propagation behavior will include and more weighted on diffraction and reflections. And since there are obstacles on the line of sight, the reference point could not be the 1 meter free space.  Using CI model in the NLOS case will underestimate the propagation loss in that case.  2, the frequency dependency should be studied, but is not preferred to used 20\*log10(fc) in the NLOS case.  The frequency dependency of 20\*log10(fc) is also from the free space propagation. As illustrated in above, diffractions and reflections weights more in the NLOS case. Due to the additional loss of diffractions and reflections, the frequency dependency should not still be 20\*log10(fc). | * ABG model is preferred * Frequency-dependency should be further studied. And the 20\*log10(fc) should not be simply reused. |
| Fraunhofer IIS | The CI model for NLOS is overestimating the PL at short TX-RX distance, and underestimating it at large TX-RX distance. | * ABG model is preferred. * However, so many degrees of freedom might generate divergent result in the different scenarios that could later difficult the merging process of the parameters |

## 2.2 LOS probability

The following agreements with relevance to the LOS probability modeling were reached at RAN1#96b and RAN1#97:

Agreements:

Modelling on the spatial consistency of LOS probability should be supported with followings:

* As a starting point, reuse the “soft LOS” in TR38.901 to model the LOS/NLOS transition
  + Companies are encouraged to provide the value of auto-correlation distance of LOS state
* The LOS states for different BS-UT links for the same UT are assumed to be independent as baseline
  + Cross-correlation of the LOS probability among such links can be considered if simulation/measurements data are available

Agreements**:**

Use a common LOS probability function for all sub-scenarios, with sub-scenario specific parameters:

* + Where
  + is the 2D distance between transmitter and receiver;
  +  is the breakpoint distance
  +  is the breakpoint LOS probability
  +  is the exponential coefficient for corresponding sub-scenario
  + The parameter values for the different sub-scenarios is FFS, including:
    - how to merge results from different sources
    - whether the parameter values should be obtained from empirical curve-fitting or analytical considerations
    - whether the parameters should be dependent on the clutter density and size

In line with the above agreements, companies are encouraged to share their views on the remaining details of the LOS probability modeling below, including the parameterization of the LOS probability function for the different sub-scenarios.

**L1: Please provide views and parameter proposals for the LOS probability functions**

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| **Company** | **Views on the LOS probability functions** | **Proposals** |
| Ericsson | In R1-1907703 we derived the LOS probabilities for a canonical scenario as in the following figure.    For clutter-embedded scenarios the LOS probability is  For elevated BS scenarios the LOS probability is  In both cases, is the clutter density and and is the typical clutter size/width and clutter height.  These functions may appear different than the agreed exponential function for LOS probability, but can in fact be rewritten on the exponential form with , , and , where is the exponent in the above expressions, e.g. for the clutter-embedded scenarios.  Obviously, the canonical scenario is a bit simplified compared to actual industrial environments since it uses a constant clutter height and clutter width. However, it captures the essentials of the LOS probability dependence on such parameters. | * The LOS probability is for sub-scenarios with clutter-embedded BS and for sub-scenarios with elevated BS, where , is the clutter density and and is the typical clutter size/width and clutter height * FFS on the choices of , , and for the different sub-scenarios |
| Nokia | Our view is aligned with the stated by Ericsson above. We aim at fitting a simple exponential decay model per sub-scenario with as few input parameters as possible (i.e. clutter density and typical average clutter/machinery size or inter-machinery distance), similar to what we stated in R1-1810659. | * Define LOS probability functions in terms of clutter density and typical average clutter/machinery size or inter-machinery distance. |
| ZTE | In a factory or workshop, clutters are usually distributed in 3D space with different height/length/width and some of them are hollow or heteromophic, so we prefer a simple empirical model as agreed in RAN1#96b. | * Use a common LOS probability function for all sub-scenarios, with sub-scenario specific parameters as agreed in RAN1#96b. |
| Qualcomm | In many industrial environments, the clutter height/size can be highly variable. The impact of this variation should be included in the LOS probability modeling. | * Consider modeling the impact of variable clutter height/size on the LOS probability. |
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**L2: Please provide views on how to merge LOS data from different sources**

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| **Company** | **Views on LOS data merging** | **Proposals** |
| Ericsson | So far there has been two types of contributions on LOS probabilities: the empirical fitting of parameters based on ray-tracing simulations by ZTE in R1-1907126, and the analytical derivations based on a simple canonical scenario by Ericsson as described in our reply to L1 above. To check whether these two approaches generate results that are consistent with each other we have tried to reproduce some of the empirical curves using the analytical functions. For this, we have focused on Area 2 in the contribution from ZTE since this was the easiest in which to provide a fair comparison. Using clutter number and size information for Area 2 provided by ZTE, the following parameters are estimated: , , . Below are two figures comparing the analytical LOS probabilities using these settings with the empirical (ray-tracing) results for Area 2.      There is a quite good match between the empirical and analytical results in the clutter-embedded case. Also, in the elevated BS case the correspondence is very good for hBS = 15 m though the analytical expression is somewhat more sensitive to the BS height than the ray-tracing results. However, the differences are small enough that it can be argued that the analytical expressions are adequate for capturing the ray-tracing results  Our main motivation for pursuing the analytical expressions is that these can be used to predict the LOS probability for other antenna heights and clutter parameters than what is used in specific ray-tracing experiments. At this point, the main uncertainty associated with this approach is in how to determine the average clutter parameters , , and in a real industrial hall scenario with possibly many types of objects of different sizes. Possibly one can tune these parameters rather than directly determine them for better correspondence with the empirical results. | * Adopt the analytical expressions for the LOS probability that we provided in our response to L1 since these seem to be able to reproduce the ray-tracing results in a homogeneous area with sufficient accuracy   + FFS on how to determine the average clutter parameters , , and for the defined sub-scenarios or for a real industrial hall, e.g. if tuning of these parameters rather than direct estimation from the clutter info can provide better accuracy. |
| Nokia | We believe that both Ericsson’s and ZTE’s analytical and simulation works are valid to model the LOS probability in industrial scenarios. We suggest blending all results and fit a simple exponential decay model based on scenario parameters as stated above stated. | * Fit a simple exponential decay model to the available analytical and simulated distributions, considering variable clutter density and typical average clutter size per dub-scenario. |
| ZTE | As mentioned in Ericsson’s view, in some sub-scenarios, the curve generated by Ericsson’s formula matched well with the empirical result by ZTE ray tracing results and the relationship between *ksubsce* and *r*,*dclutter* etc can be derived if , , so in these sub-scenarios, maybe we can add a note to suggest how to conclude *ksubsce* by *r, dclutter etc* for a canonical scenario. | * In some sub-scenarios, e.g. low clutter density with BS elevated or embedded, add a note to suggest how to conclude *ksubsce* by *r, dclutter etc* for a canonical scenario. |
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**L3: Please provide input on the spatial consistency of the LOS state, including the auto-correlation distance and the cross-correlation of the LOS state among links from the same UT to different BS**

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| **Company** | **Views on the spatial consistency of the LOS state** | **Proposals** |
| Ericsson | As argued in R1-1907703, the autocorrelation distance of the LOS state will depend on the specific factory hall layout and the typical sizes of the objects representing the clutter. The LOS state may change with different rates in different directions, e.g. it can change much faster when going across an aisle than along the same aisle. However, for simplicity and consistency with the modeling framework used for the other scenarios we propose to use a single scalar value for the autocorrelation distance. In our answer to L1 above we derived LOS probability curves assuming a typical clutter size/width . This parameter can be reused also as the autocorrelation distance. | * For the autocorrelation distance of the LOS state, use , where is the typical clutter size/width (note: same parameter as proposed for the LOS probability function) |
| Nokia | LOS correlation distance should be proportional to the typical average clutter/machinery size present in each of the sub-scenarios. |  |
| ZTE | In R1-1904117, the correlation distance is provided according to simulation:  ***Proposal :*** *The correlation distance of LOS probability is given by*   * *For BS above the clutter: 20m;* * *For BS embedded in clutter: 18m.* | ***Proposal :*** *The correlation distance of LOS probability is given by*   * *For BS above the clutter: 20m;* * *For BS embedded in clutter: 18m* |
| Qualcomm | Given the sizable likelihood of multi-TRP based operation in industrial environments, modeling the cross-correlation of the LOS state between UT and different TRPs/gNBs should be considered essential. Available measurements and/or the ray-tracing framework discussed earlier for other parameters should be utilized. | * Cross-correlation of the LOS state between UT and different TRPs/gNBs should be modeled based on available measurement and/or ray-tracing simulation results. |
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## 2.3 Fast fading

The following agreements with relevance to the LOS probability modeling were reached at RAN1#96b and RAN1#97:

Agreements:

Use the fast fading modelling framework of TR 38.901 for the industrial scenario

* Companies are encouraged to provide contributions on parameter values for the different sub-scenarios
* For parameters where there are no measurements, use values from InH as the baseline
  + Note: The InH parameters may be “smartly adapted”

Agreements:

The hall volume dependence of the channel model parameters such as the delay spread is FFS

* Companies are encouraged to provide CDFs and percentiles + parameterizations per sub-scenario

Agreements:

FFS on how to capture the dense multipath as observed in some measurements

* Options could include:
  + Increasing the number of clusters to emulate the dense multipath but keeping fixed 20 rays per cluster according to the modeling framework

Agreements**:**

Add an additional sub-scenario where both Tx and Rx are elevated above the clutter

* Use the same path loss model as sub-scenarios 3 & 4 as a starting point
* Use 100% LOS
* Use the same fast fading model and parameters as sub-scenarios 3 & 4 as a starting point
  + FFS on updates to these values if measurements or simulation results become available

Agreements**:**

For compiling a full table for the LSP parameters, proceed as follows:

* Collect LSP proposals from all companies using the excel file in R1-1907407 as the template
* Merge these proposals into a single table
  + In case of conflicting proposals, decide on a case-by-case basis whether one proposal should be used or some averaging or merging should be performed
  + In case of missing parameters, reuse values from similar sub-scenarios or from InH
* Use the compiled table as the starting point for the fast fading modeling (i.e. put the values in square brackets)
  + Further review may be necessary to ensure that the parameter values are compatible with each other
  + Additional contributions , e.g. an email discussion after RAN1#97, are encouraged
* Set cross-correlations that have absolute values less than 0.5 to zero to simplify the model.
* Companies are encouraged to verify the statistical confidence especially on the high cross-correlation values.

Agreements**:**

Use a model for the rms delay spread that is dependent on the hall volume

* FFS on whether to use common or separate rms delay spread parameterizations per sub-scenario
* FFS on the need for frequency- and distance-dependence

In line with the above agreements, companies are encouraged to share their views on the remaining details of the fast fading modeling below. It is particularly encouraged to propose LSP parameterizations for the different sub-scenarios using the attached excel file.

**F1: Please provide LSP parameter proposals in the attached excel file, which is based on the excel file in R1-1907407 [5]**

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| --- | --- |
| **Company** | **Comments on LSP parameter proposals** |
| Ericsson | We have provided our proposals on the following LSPs in the excel file “LSP parameter proposals\_v2.xls”:   * A hall volume dependent rms delay spread as motivated in R1-1907412 * RMS angular spreads, Ricean K-factors, and XPR values according to the results of the literature study in R1-1813129 |
| Nokia | We have added our input to LSP parameters in the attached excel file “LSP parameters proposals\_v2\_nokia.xls”.   * We consider our DS results from R1-1902624 as properly included in the model proposed by Ericson above. * We have included AOD results from R1-1902623. * We have included XPR results from R1-1904825. |
| ZTE | We have added our proposals on the excel file attached: “LSP parameters proposals\_v2\_nokia\_ZTE.xls”:   * RMS DS in R1-1906492 with hall size 360000 m3. * K-factor in R1-1902114, distance dependent-K\_factor is proposed. |
| CMCC | We have added our proposals on the excel file attached: “LSP parameters proposals\_v2\_nokia\_ZTE\_CMCC(v2)\_DCM.xls”:   * 4.9GHz RMS DS in R1-1904743 with hall size 42000 m3.   + In LOS, Mean = -6.907, std = 0.186   + In NLOS, Mean = -6.820, std = 0.1727 * 28GHz RMS DS with hall size 42000 m3.   + In LOS, Mean =-7.32 (47.86 ns), std = 0.23   + In NLOS, Mean =-7.17 (67.61ns), std = 0.30 |
| NTT DOCOMO | We have added our proposals on the excel file attached: “LSP parameters proposals\_v2\_nokia\_ZTE\_CMCC\_DCM.xls”. These values are measurement results explained in R1-1906232 and hall size is 28m by 35m by 10m = 9800 m^3. |

**F2: Please provide additional views on LSPs including details on how to merge proposals from different sources, how to capture dense multipath, etc**

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| **Company** | **Additional views on LSPs, data merging, dense multipath, etc** | **Proposals** |
| Qualcomm | As indicated earlier in R1-1903023, literature suggests that in some industrial environments a significant fraction of power may be received over dense multipath components, rather than a few specular multipath components – used, e.g., in the indoor-hotspot model in 38.901. | * Consider modeling the impact of a sizable fraction of the received power being over dense multipath components. |
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## 2.4 Other model details including scenario description and additional model components

The following agreements with relevance to the scenario description have been reached at RAN1#96b and RAN1#97:

Agreements:

A new Indoor - Industrial scenario (IIoT) is added to TR 38.901

* This scenario can have one or more sub-scenarios where some environment parameters and/or channel model parameters may differ between the sub-scenarios (note: compare InH-open office and InH mixed office in 38.901)
  + A sub-scenario is defined by the range of validity of the environment parameters and the channel model parameters
  + FFS on the number and details of these sub-scenarios, including homogeneity or heterogeneity of environment parameters and channel model parameters within a sub-scenario
* When possible, the channel model components should cover the range of the environment parameters of the different sub-scenarios
  + E.g. a LOS probability model with a functional dependence on the clutter density is preferable to separate LOS probability models for different clutter densities
* For channel model calibration purposes, the sub-scenario description can be complemented with additional simulation assumptions, including:
  + BS deployment and user distribution
  + Mobility
  + Antenna models
  + Output powers and noise figures
  + etc

Agreements**:**

Adopt a sub-scenario according to the table below

* Note: Further sub-scenarios may be adopted if needed

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| **Parameters** | | **Sub-scenario 1** |
| Layout | Room size | Rectangular: [FFS, e.g. 5000-20000 m2] |
| Ceiling height | [FFS: e.g. 10-25 m] |
|  | External wall type | [Concrete walls with metal-coated windows] |
| Clutter type | | [Small to medium metallic machinery and objects] |
| Clutter density and distribution | | FFS |
| Clutter height | | FFS |
| BS antenna height *h*BS | | [clutter-embedded or above clutter] |
| UT location | LOS/NLOS | LOS and NLOS |
| Height *h*UT | [Clutter-embedded] |

Agreements:

The baseline scenario may be extended by any of the following options

* Sources of EM interference: TBD how to specify
* Clutter mobility: TBD how to specify
* Mobile gNBs or D2D communication leading to dual mobility

Agreements:

Introduce four industrial sub-scenarios

* Sub-scenario 1: Low clutter density, both Tx and Rx antennas are clutter-embedded (LOS or NLOS)
* Sub-scenario 2: High clutter density, both Tx and Rx antennas are clutter-embedded (LOS or NLOS)
* Sub-scenario 3: Low clutter density, one of Tx or Rx is elevated above the clutter (LOS or NLOS)
* Sub-scenario 4: High clutter density, one of Tx or Rx is elevated above the clutter (LOS or NLOS)
* Definition of “low” and “high” clutter density is FFS
* As a starting point, a common set of fast fading parameters are used for LOS in all four sub-scenarios
* FFS if other parameters can be merged across scenarios
* Companies are encouraged to provide parameterizations for each of the sub-scenarios
  + Path loss model
  + LOS probability
  + Fast fading model parameters
* FFS on the need for further sub-scenarios, e.g. for sensors embedded within cubicles or machinery

Agreements**:**

In the scenario description of sub-scenarios 1-4, the factory hall size and height are given by

* Hall size is [20]-[160000] m2, ceiling height is [3]-[25] m
  + Note: The sizes may be different for different sub-scenarios
  + Note: The range may be collapsed into a single value

Agreements:

Specify the external wall and ceiling type for the sub-scenarios 1-4 as “concrete or metal walls and ceiling with metal-coated windows”

* Note: For worst-case coexistence or interference evaluations, low loss external wall type may need to be considered
* Note: FFS on need for specifying internal walls and floor/ceiling for multi-floor or multi-hall factories

Agreements**:**

Clutter density can be defined as the percentage of area occupied by clutters inside factory. Threshold between high density and low density is FFS.

* Note: Whether the clutter is solid or hollow may also affect the effective clutter density
* Considerations on clutter height is FFS
* Companies are encouraged to quantify the clutter density in their studies

**Agreements:**

For the industrial scenario description, do the following:

* Add specific values (details FFS) for volume or size of room for each sub-scenario for calibration purposes
* In the clutter type, add a general description of the clutter characteristics
  + FFS on details, e.g. examples of typical industrial clutter

The following table aims to capture the essential traits of the above agreements. Companies are encouraged to provide views below on any remaining items related to the scenario description.

Table 7.2-4: Evaluation parameters for Indoor Industrial

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | Indoor Industrial | | | | |
| Parameters | | Sub-scenario 1 | Sub-scenario 2 | Sub-scenario 3 | Sub-scenario 4 | Sub-scenario 5 |
| Layout | Room size | Rectangular: [20-160000] m2 | Rectangular: [20-160000] m2 | Rectangular: [20-160000] m2 | Rectangular: [20-160000] m2 | Rectangular: [20-160000] m2 |
| Ceiling height | [3-25] m | [3-25] m | [3-25] m | [3-25] m | [3-25] m |
|  | External wall and ceiling type | Concrete or metal walls and ceiling with metal-coated windows | | | | |
| Clutter type | | [Small to medium metallic machinery and objects] | [Small to medium metallic machinery and objects] | [Small to medium metallic machinery and objects] | [Small to medium metallic machinery and objects] | [Small to medium metallic machinery and objects] |
| Clutter density and distribution | | Low clutter density | High clutter density | Low clutter density | High clutter density |  |
| Clutter height | | FFS | FFS | FFS | FFS | FFS |
| BS antenna height cid:image001.png@01D4B35D.C4D8CCE0 | | clutter-embedded | clutter-embedded | above clutter | above clutter | Above clutter |
| UT location | LOS/NLOS | LOS and NLOS | LOS and NLOS | LOS and NLOS | LOS and NLOS | 100% LOS |
| Height cid:image003.png@01D4B35D.C4D8CCE0 | Clutter-embedded | Clutter-embedded | Clutter-embedded | Clutter-embedded | Above clutter |

**O1: Please provide views on remaining items in the scenario description**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on remaining items in the scenario description** | **Proposals** |
| Ericsson | The clutter height clearly differs between different factory halls and scenarios. Apart from the obvious limitations with respect to base station height in the different sub-scenarios, it is proposed to provide a reasonable range for the clutter height. However, for channel model calibration, specific clutter height can be specified, especially if a clutter height-dependent LOS probability function is adopted.  Similarly, the “low” and “high” clutter density categories may also encompass a range of values. We therefore propose to use a range, e.g. 0-10% for low density and 15-30% for high density. Again, specific values may be assumed for channel model calibration. | * Specify the clutter height as 1-10 m * Define low clutter density as 0-10% area occupancy and high clutter density as 15-30% area occupancy   + Note: the clutter height is smaller or larger than the base station height for the corresponding embedded or elevated sub-scenarios   + Note: for calibration purposes, specific values for clutter height, size, and density should be specified |
| Nokia | It would be reasonable to keep the open ranges for the layout parameters as “room size” and “ceiling height”. The “clutter height” could be also included as layout parameter (ensuring that clutter height < ceiling height. With respect to “low” and “high” clutter reference densities, we suggest waiting and base the decision on the values reported by the companies in the measurement summary spread sheet – so far, only Nokia has reported clutter densities from measurement scenarios and literature. | * Include clutter height as layout parameter as an open range ensuring that clutter height < ceiling height. * Clutter density FFS based on the values reported by the different companies in the measurement summary. |
| ZTE | At least, the reasonable range for “room size”, “ceiling height” and “clutter height” shall cover the values reported by companies and the open ranges are acceptable as well. |  |
| Qualcomm | Instead of a single clutter height, a distribution with per sub-scenario parameter values may provide more realistic modeling. | * Consider specifying the clutter height distribution with per sub-scenario parameters. |
| NTT DOCOMO | We do not think we need definition of clutter height, so we do not have strong view on clutter height.  Regarding clutter density, we think each party should classify measurement environments in which area occupancy are clear into high clutter density case and low clutter density case, then we will decide threshold based on above results of classification. | Following process can be considered to decide threshold between high and low clutter density case.  Each party is encouraged to calculate area occupancy of measurement environment.  Each party classify above measurement environment into high or low clutter density case considering picture or layout etc. of environment.  Obtain min value of high clutter density case and max value of high clutter density case then, average of both values can be treated as threshold. |

The following agreements related to spatial consistency have been reached at RAN1#96b and RAN1#97. Companies are encouraged to provide views on remaining items of spatial consistency below.

Agreement:

Revisit spatial consistency procedures when the fast fading model is stable

Agreements**:**

Specify the correlation distances for spatial consistency for the industrial scenario.

* Use [10] m for the cluster and ray specific random variables as a starting point
* FFS on need to distinguish between sub-scenarios
* Additional measurements or simulation results are encouraged

Agreements:

Consider refinements to the spatially-consistent mobility modeling procedures in TR 38.901, e.g., Procedure A in section 7.6.3.2, to enable more accurate channel modeling for positioning.

**O2: Please provide views on remaining items on the modelling of spatial consistency**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on the modeling of spatial consistency** | **Proposals** |
| Nokia | Correlation distances for spatial consistency should be equal or at least comparable to those of the obstacles producing LOS/NLOS state conditions (i.e. machinery or clutter width/size). |  |
| ZTE | The correlation distance for LOS/NLOS state and for cluster and ray specific random variables are two different values. Usually the former is larger than the latter, especially for the large area or hall size, e.g. 5G-ACIA scenario.  In R1-1904117, the correlation distance is provided according to simulation:  ***Proposal :*** *The correlation distance of LOS probability is given by*   * *For BS above the clutter: 20m;* * *For BS embedded in clutter: 18m.* | ***Proposal :*** *The correlation distance of LOS probability is given by*   * *For BS above the clutter: 20m;* * *For BS embedded in clutter: 18m* |
| Qualcomm | With respect to the spatial-consistency modeling for positioning, the specified update distance limit of 1m in Procedure A may be too coarse for precise positioning, as discussed in R1-1907301. Hence, setting a lower limit should be considered. | * Consider refining the update distance limit in Procedure A for the spatial-consistency mobility modeling in TR 38.901. |
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The following agreements related to blockage have been reached at RAN1#96b and RAN1#97. Companies are encouraged to provide views on remaining items of blockage below.

Agreements:

The blocking model in 38.901 may be adapted for industrial scenarios as an additional component

* Derive new model parameters for Blocking models A and B to represent industrial objects (AGVs, robots)
  + Companies are encouraged to provide parameters
  + The resulting blocking loss should be checked against measurements
  + FFS to understand the combination of shadow fading and blocking model

Agreements**:**

specify the following types of blockers for use with Blocking model B:

* Human – with dimensions and mobility pattern same as for indoor and outdoor scenarios
* AGVs or moving trains – dimensions and mobility pattern FFS
* Industrial robot– dimensions and mobility pattern FFS
* FFS on the need for specifying the number and density of the blockers

Agreements**:**

Consider whether and how any change to Blocking model A is needed for multi-TRP

**O3: Please provide views on the remaining items for modelling of blockage**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on the modeling of blockage** | **Proposals** |
| Ericsson | For blocking model B it was agreed in Reno to specify AGVs/moving trains and industrial robots. There are many types of such devices for different purposes and of different sizes. Based on sources/photos on the internet, the following parameters are proposed for these types of blockers:  AGV: 3x1.5 m (WxH), up to 30 km/h  Industrial robot: 2x0.2 m (WxH), up to 3 m/s | * Provide the following recommended parameters for the new industrial blocker types for blockage model B:   + AGV: 3x1.5 m (WxH), up to 30 km/h   + Industrial robot: 2x0.2 m (WxH), up to 3 m/s |
| Qualcomm | TR 38.901 considers blockage modeling as an add-on feature. Given the significant impact on the key KPIs in industrial scenarios, blockage modeling should be strongly encouraged for such scenarios.  For consistency, explicit values/ranges of the number/density of blockers and their size distribution should be specified in Model B, which can be different for the different sub-scenarios being considered. | * Given typically high-reliability requirements, as well as likely presence of many blockers, in industrial use-cases, RAN1 should strongly recommend blockage modeling for industrial scenarios. * Consider specifying explicit values of the number/density of blockers and their size distribution in Model B for different industrial sub-scenarios. |
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The following agreements related to absolute time of arrival have been reached at RAN1#96b and RAN1#97. Companies are encouraged to provide views on remaining items of absolute time of arrival below.

Agreements**:**

* Absolute time of arrival of multipath components in LOS and NLOS is added as an additional modeling component
  + Note: This modeling component is provided to support simulations in which absolute time of arrival is important (e.g., ToA based positioning)

Agreements:

* Add an additional delay 0 to all cluster delays for absolute time of arrival modeling
* In LOS, 0 = d3D/c
* In NLOS, 0 = d3D/c + 
  + FFS on how to model , e.g. by random or deterministic procedure

Agreements:

For absolute delay modeling, use a random distribution to model  in NLOS conditions

* FFS on the choice of random distribution, e.g. among the below (or other) options:
  + Option 1:  follows a lognormal distribution, with different parameterization per sub-scenario
  + Option 2: follows an exponential distribution
  + Option 3: follows a Gaussian distribution, truncated so that  >=0
* The value for  should be upper bounded
  + FFS whether the upper bound should depend on the cluster powers in relation to the path loss
* FFS on the need for modelling inter-link correlations for the LOS/NLOS state and for 

**O4: Please provide views on the remaining items for absolute time of arrival, e.g. distribution and parameters for , the upper bound for , and the need for modeling inter-link correlations for the LOS state and for **

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on remaining items for modeling of absolute time of arrival** | **Proposals** |
| Ericsson | We do not have any strong opinion on the choice of random distribution for , as with reasonable parameter choices they are fairly similar, and possibly can all be used to represent the measurement or simulation data. As for the upper bound to , the principle should be that the NLOS path loss at the physical LOS distance d3D should be at least as high as the free space path loss at the propagation distance d3D + c. This can be reformulated into a condition on an upper bound of as a function of distance and NLOS path loss. | * Put an upper bound on so that the NLOS path loss is always larger than the free space loss at distance |
| Nokia | We agree with the above views. We believe that stochastic modelling of , using data from measurements or ray-tracing would be the more correct way to characterize absolute time of arrival in NLOS conditions, but we do not have any strong opinion on the choice of exact random distribution to be used. | * Use a random distribution to model in NLOS conditions. |
| ZTE | 1. We prefer Option 1:  follows a lognormal distribution and the universal parameterization for all sub-scenarios is acceptable. 2. In a multi-path abundant scenario, the NLOS path loss may be less than the loss derived by free space loss equation, so we suggest to constraint the in cluster level but in path loss level. | Use Option 1:  follows a lognormal distribution with the universal parameterization for all sub-scenarios.  Free space loss constraint is utilized in cluster only. |
| Qualcomm | For the distribution of , the option that provides the best fit to the available measurements should be considered. |  |
| NTT DOCOMO | As we described in R-1906233, we think log of ****can be approximated by Gaussian distribution. | Absolute time of arrival in NLOS environment is given by  lg =log10()  where d3D is 3D distance between BS and MS (m), c is speed of light (m/s) and (s) is additional delay which is lg ~N (, ). Value of and are -7.3 and 0.22 respectively. |

The following agreements related to dual mobility have been reached at RAN1#96b and RAN1#97. Companies are encouraged to provide views on remaining items of dual mobility below.

Agreements**:**

* Doppler due to moving clutter or dual mobility is added as an optional feature in the model
  + Note: the channel coefficient equations will need to be updated for these cases

Agreements:

The Doppler model considering dual mobility shall be based on TR 37.885. The random component due to scatterer mobility is FFS

* Note: Random Doppler of moving scatterers may be different in the industrial scenario than in V2X

Agreements:

dual mobility should be modeled as follows:

* Doppler for the LOS path:

,





* Doppler for the delayed paths:

where is a random variable from to , is the maximum speed of the clutter. The distributions of and should be FFS.

* To account for the fact that most scatterers are stationary, the random variable should be 0 for most combinations of n and m but could be 1 with some low probability.

**O5: Please provide views on the remaining items of dual mobility, specifically on the distributions of and**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on remaining items for dual mobility** | **Proposals** |
| Ericsson | The random variable can be understood as the radial velocity of the scatterer in relation to the scattered wave. A uniform distribution between and may be a simple but sufficiently useful model for .  The random variable can be understood as specifying whether the scatterer giving rise to the n.m:th multipath is stationary or moving. A binary random distribution {0,1} with certain probability of a 1 seems appropriate. The exact probability can be left as a simulation assumption to allow simulations with different levels of clutter mobility. | * Use a uniform random distribution for * Use a binary random distribution {0,1} for where the probability of may be left as a simulation assumption |
|  |  |  |
|  |  |  |
|  |  |  |

## 2.5 Calibration assumptions including metrics

The following table was agreed in RAN1#96b as a starting point for the channel model calibration. Companies are encouraged to provide their views below on remaining items for the calibration assumptions including further necessary simulation assumptions and the metrics that should be compared in the calibration campaign.

Table 7.8-2: Simulation assumptions for large scale calibration for the indoor industrial scenario

|  |  |
| --- | --- |
| Parameter | Values |
| Scenario | Indoor industrial – sub-scenarios 1-4 |
| Room size | 100x100 m |
| Room height | 10 m |
| Sectorization | None |
| BS antenna configurations | 1 element (vertically polarized), Isotropic antenna gain pattern |
| UT antenna configurations | 1 element (vertically polarized), Isotropic antenna gain pattern |
| Handover margin (for calibration) | 0dB |
| BS deployment | Rectangular grid with ISD = 20 m, FFS on exact grid and number  BS height = [1.5] m or 8 m |
| UT distribution | uniform dropping for indoor with minimum distance ([2D or 3D]) of [1] m  UT height = 1.5 m |
| UT attachment | Based on pathloss |

**C1: Please provide views on the remaining items for the simulation assumptions for calibration**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on remaining items for calibration simulation assumptions** | **Proposals** |
| Ericsson | The proposed combination of vertical polarization and isotropic antenna pattern results is an issue with undefined polarization in the =0° and =180° directions. To avoid this, it is proposed to change the antenna pattern to that of a half-wave dipole at both Tx and Rx. Furthermore, to avoid issues with minimum dropping distance the base station height could be changed to 2 m.  Some additional simulation assumptions need to be specified to avoid ambiguity in the results. The following items may be used as a starting point:  BS tx power: 30 dBm  BS deployment: in locations with x and y coordinates 10, 30, 50, 70, 90 m, i.e. 25 locations in total  UT noise figure: 9 dB  Carrier frequency: 3.5 GHz, 28 GHz  Bandwidth: 20 MHz for 3.5 GHz, 100 MHz for 28 GHz | * Use the following simulation assumptions for calibration of the indoor industrial scenario:   + Use half-wave dipole antenna patterns at BS and UT   + BS height is 2 m   + BS tx power: 30 dBm   + BS deployment: in locations with x and y coordinates 10, 30, 50, 70, 90 m, i.e. 25 locations in total   + UT noise figure: 9 dB   + Carrier frequency: 3.5 GHz, 28 GHz   + Bandwidth: 20 MHz for 3.5 GHz, 100 MHz for 28 GHz |
| Nokia | We are fine with the above proposal by Ericsson. | |
| ZTE | We are fine with most of the proposals by Ericsson except the antenna type due to isotropic antenna can reflect channel result better decoupled from antenna pattern compared with half-wave dipole, so  **Proposal: An isotropic antenna with d2Dmin=0.1m constraint.** | Proposal: An isotropic antenna with d2Dmin=0.1m constraint. |
| Qualcomm | We agree with the Ericsson’s proposal. |  |
|  |  |  |

**C2: Please provide views on the metrics that should be used in the channel model calibration**

|  |  |  |
| --- | --- | --- |
| **Company** | **Views on calibration metrics** | **Proposals** |
| Ericsson | For calibration of the path loss and LOS probability model implementations, it is suitable to use the serving cell coupling loss and the geometry as metrics.  For calibration of the fast fading aspects, the delay and angle spreads are suitable metrics.  In case the calibration should also cover the absolute delay modeling, the CDF of the first path excess delay (e.g. ) can be a suitable metric | * The following metrics are proposed for the channel model calibration:   + 1) Coupling loss – serving cell   + 2) Geometry with and without noise   + 3) CDF of delay and angle spread (ASD, ZSD, ASA, ZSA) according to definition in Annex A.1 of TR 38.901   + 4) CDF of first path excess delay for serving cell |
| Nokia | We are fine with the above proposal by Ericsson. | |
| ZTE | We are fine with the above proposal by Ericsson. |  |
| Qualcomm | We also are ok with the Ericsson’s proposal. |  |
|  |  |  |

## 2.6 Other items

Please provide input on other topics that are of importance for completion of the tentative model specification and to support channel model calibration, if any.

**X1: Please provide input on any other topics needed for the tentative model specification or to support the channel model calibration campaign**

|  |  |  |
| --- | --- | --- |
| **Company** | **Additional input** | **Proposals** |
| Nokia | Similar to what was done for Urban Macro, urban Micro, Indoor and O2I, the final TR should contain the list of measurement contributions to the model from the different sources. | * Update Table 6.3-1 in TR 38.901 to capture the measurement contributions to the industrial channel model. |
|  |  |  |
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# References

1. RP-182138, SID on Channel Modeling for Indoor Industrial Scenarios, Ericsson, 3GPP TSG-RAN Meeting #81, Gold Coast, Australia, September 10th – 13th 2018.
2. R1-1907920, List of agreements, Ericsson, RAN1#97, Reno, USA, May 13-17, 2019.
3. R1-1907940, Addition of indoor industrial channel model, Ericsson, RAN1#97, Reno, USA, May 13-17, 2019.
4. R1-1907405, Summary of email discussion on path loss, Ericsson, RAN1#97, Reno, USA, May 13-17, 2019.
5. R1-1907407, Summary of email discussion on fast fading, Ericsson, RAN1#97, Reno, USA, May 13-17, 2019.