Channel Generation (TR 38.901)

Tang Chao

sisy710.ee04@g2.nctu.edu.tw

National Yang Ming Chiao Tung University

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Fast fading model from TR 38.901 Sec. 7.5. The following steps follow the Fig. 7.5-1 in the document. The red text indicates modifications by me. Input/Output of each step.

- General parameters.
  - Set scenario, network layout, and antenna parameters. Disregard antenna patterns
  - Assign propagation condition (LOS/NLOS). All devices are set outside. All AP-IRS links are LOS.
  - Calculate pathloss.
  - Generate correlated large-scale parameters(LCPs): delay spread(DS), angular spread(AS), shadow fading(SF), K-factor(K), and XPR related parameters. They mostly depends on the carrier/central frequency.
    - LCPs are random variables. Once generated, they are used to generate other stochastic parameters (small-scale parameters such as AoA/AoDs).
    - The cross-correlation between UTs served by the same BS is also considered by applying 2D LTI filters to the generated numbers.

- Small scale parameters.
  - Generate delays for each cluster with exponential delay distribution using DS and K.
  - Generate Cluster Powers P_n with delays and DS. (modeled as a single slope exponential power delay profile.)
  - Generate the mean arrival and departure angles for each cluster (AOA, AOD, ZOA, ZOD) using the following method.
    - First, the LOS direction of each cluster is calculated according to the positions of BSs and UTs (UEs).
    - For each cluster, the angles are calculated by adding an offset to the LOS directions. The offset include two components:
    1. Deterministic component: The composite power angular spectrum(PAS) is modeled as wrapped Gaussian in the azimuth and Laplacian in the zenith. The corresponding angle offsets of each cluster are generated using inverse functions with the power of each cluster as input.
    2. Stochastic component: A Gaussian random variable determined by AS.
    - In summary: The angles of each cluster are generated with LOS direction, the cluster power, and AS.

- The angles of each ray/path are then generated by adding a Gaussian noise to the cluster AoA/AoDs. The variance of the noise depends on the cluster AS, which is different from AS and only depend on the scenario.
- Perform random coupling of rays.
- Generate cross polarization power ratios (XPRs).

Channel Generation Steps (4)

- Channel coefficient generation
  - Draw random initial phases, Φ, which would later be applied to each ray.
  - Generate channel coefficient (impulse response).
    - The 2 strongest clusters are spread in delay to 3 sub-clusters with fixed delay offset and power distribution.
    - For example, ray/path 1-6 will belong to subcluster 1, 7-12, will belong subcluster 2, and 13-20 will belong to subcluster 3
    - NLOS and LOS components are combined at this stage if applicable.
  - Apply pathloss and shadowing.

Next Steps

- Adapt the model's more realistic AoA/AoD (of rays) generation procedure, but disregard delay and use the original equation to generate the flat channel matrix.

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$$\mathbf{H} = \sum_n \sum_m \sqrt{\frac{P_n}{M}} exp(-j\Phi) \mathbf{a}_{Rx} \mathbf{a}_{Tx}^H$$

  where Φ is the random phase shift of each ray and $\mathbf{a}$ is the steering vector and depends on AoA/AoDs.

- Keep the original way of applying pathloss and shadowing. i.e. they are applied separately to the LOS/NLOS component of the channel.

Carrson's own summary (1)

On p. 2

- Note that the path loss model for outdoor and indoor are different
- If AP is outdoor and UEs are indoor, then we will need to have 2 pathloss models: one for outdoor and the other for indoor
    - In that case, we also need to know which area is indoor and which is outdoor (i.e. how long are the indoor and outdoor distances
- The current indoor path loss model is linear, instead of piecewise linear (this was used in an first version of our paper)
- Chao Tang simulated the delay spread (DS) because it is a parameter to generate the delay for each cluster that would allow one to calculate the cluster power. If our model needs to model frequency-selective channels, then this delay spread will be used elsewhere in the model as well

p. 3

Carrson's own summary (2)

- CT generated delay for each cluster based on the delay spread on p. 2 and also κ (K on p. 3). This is the minimum delay for all rays/paths of each cluster
  - This is needed to calculate the cluster power
- The AOA, AOD, ZOA (zenith-angle-of-arrival) and ZOD refer to the AOA/ZOA at the UE and AOD/ZOD at the AP
- The LOS direction pertains to each cluster, i.e. cluster 1, which only has 1 path
  - the LOS direction is determined by the location of the AP and UE, and the orientation of the AP and UE (only matters if it's UPA)
  - When we are talking about the NLOS component of the channel, then cluster 1 will no longer be the LOS direction, and it will only have 1 ray/path
  - The other cluster has 20 paths. This number is based on the different scenarios (e.g. urban micro)

Carrson's own summary (3)

- Even if we are talking about the NLOS component of the channel, then cluster 1 also will have 20 paths. However, even in this case, the LOS direction can still be computed even though it is blocked
- Next step, calculate the cluster mean AOA, mean AOD, mean ZOA, mean ZOD for each cluster, where this mean is the mean angle of all 20 paths, based on the following:
  - PAS refers is a power distribution w.r.t. each angle. So this is used to generate the deterministic offset from the LOS direction which will form the mean angles for each cluster. The (deterministic part of the) offset is drawn from the PAS (the distribution)
  - The stochastic part of the offset is determined by a zero-mean Gaussian distribution with AS as the variance
    - The AS is given by the scenario and the carrier frequency
  - The offset is the sum between the deterministic part and the stochastic part
  - The LoS direction + offset = the mean angles (4 of them) for each cluster.

Carrson's own summary (4)

- Even if we are talking NLOS channel, there is still going to be a LOS direction as stated above

p. 4

- the angles of each path (4 angles) are generated by a zero-mean Gaussian distribution with "cluster AS" as variance. The cluster AS is different from the AS on p. 3. The cluster AS is also given by the scenario
- Each cluster has 20 AoAs, AoDs, ZoDs, ZoAs, so the coupling is to match each AoA to each AoD, and each ZoA to each ZoD

p. 5

- The initial phases are determined by uniform distribution $(0, 2\pi)$
- 2 strong clusters, which means clusters with the highest power, are further separated into 3 subclusters (so there will be 6 subclusters)

Carrson's own summary (5)

- Due to this, the number of clusters becomes 18 (clusters) + 6 subclusters = 24 "clusters". Each cluster is assigned a different delay (that will be used in the CDL model). See Sec. 7.7 in 2020_11_3GPP_TR_38_901v16_1_0.pdf called "Channel Models for Link Evaluation"
- According to CT, the CDL (and TDL) models are simplified version what the models that she has implemented
  - Note that each 24 "clusters" will still be assigned 20 rays/paths

p. 6

- $n = 1$: N_c (index for cluster)
- $m = 1 : M = 20$ (index for paths)
- Φ refers to the initial phase on p. 5
- $P_n = n$th cluster power