Latest results from clustering and cluster tracking applied to measurements

NEWCOM D2 Meeting
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Outline

• Cluster-based channel model

• Parameterization from measurements
  – Clustering
  – Number of clusters
  – Tracking

• Results of one indoor scenario
Cluster model

- Each snapshot of a scenario consists of multiple clusters
- Each cluster consists of multiple paths
- The parameters of all paths within a cluster show the same statistics
- The parameter statistics are interdependent. These multi-variate statistics apply to the whole scenario.

From measurements to model parameters

1. Conduct measurements in specific environments
2. Estimate propagation paths using ISIS
3. Use clustering framework on each snapshot
4. Track clusters
5. Estimate cluster parameters
6. Estimate multivariate statistics of cluster parameters
Clustering framework

Clustering framework components:

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Clustering algorithm – Example with synthetic data

Allocate points to closest centroid
Recalculate centroids
KPowerMeans clustering algorithm

• Improvement of the classic K-Means algorithm

• Goal:
  – Classify $L$ MPCs into $K$ clusters, minimizing a criterion function $D$

$$D = \sum_{l=1}^{L} P_l \cdot \text{MCD}(x_l, c_{l_l}), \quad c_k = \frac{\sum_{j \in c_k} (P_j \cdot x_j)}{\sum_{j \in c_k} P_j}$$

$I_l$ : cluster number for the n-th MPC
$c_k$ : MPC indices belonging to the k-th cluster

• Improvements:
  – Using MCD as the distance metric [Steinbauer et al., 2002]
  – Including weights (MPCs power) [VTC Fall 2006]

How to find the number of clusters, $K$?
**Number of clusters by model-based criterion**

For $K = K_{\text{min}}$ to $K_{\text{max}}$, number of clusters:

- Estimate cluster parameters for $K$ clusters
- Recreate environment using the model using $K$ clusters
- Compare modelled environment to measured environment
  - Metric for quantification of the difference was introduced: “Mismatch of Environment Characterization Metric (ECM)” [submitted to IST Summit 2006]
- If the modelled environment is “close enough” to reality, stop.
  Optimum number of clusters = $K$
- Else, Next $K$

**Advantage:**
- The number of clusters is mathematically defined by a tradeoff between model complexity and modelling error

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**Environment characterization metric (ECM)**

- **Path parameters:**
  $$\pi_l = [\tau_l^{(n)} x_{\text{TX},l} y_{\text{TX},l} z_{\text{TX},l} x_{\text{RX},l} y_{\text{RX},l} z_{\text{RX},l}]^T, \text{ and } |\gamma_l|^2$$

- **ECM is covariance matrix of all paths within one snapshot:**
  $$C_\pi = \frac{\sum_{l=1}^L |\gamma_l|^2 (\pi_l - \bar{\pi})(\pi_l - \bar{\pi})^T}{\sum_{l=1}^L |\gamma_l|^2}, \quad C_\pi = U\Sigma V^H$$

- **Mismatch of two different snapshots**
  $$\mathcal{E} = \frac{1}{D} \sum_{d=1}^D \left| \hat{\sigma}_{d,[\text{dB}]}^2 - \bar{\sigma}_{d,[\text{dB}]}^2 \right| < 0.3$$

  sorted SVs of ECM for scenarios to be compared
Results...

Measurements

- Elektrobit PropSound CS channel sounder
- Omni-directional arrays at Tx and Rx
- 2.55 GHz and 5.25 GHz
Cluster parameters in OLOS regions

2.55 GHz
5.25 GHz
Cluster parameters for 2.55 GHz in OLOS and LOS

![Cluster parameters for 2.55 GHz in OLOS and LOS](image)
Summary and conclusions

• Fully automatic procedure to obtain cluster parameters:
  – Minimum of input parameters required
  – Number of clusters obtained by model-based criterion
  – Cluster tracking over subsequent snapshots only

• Results for one indoor scenario:
  – Only small differences between 5.25 and 2.55 GHz in
    • absolute cluster power
    • number of clusters
    • cluster spreads
  – Differences between LOS and NLOS:
    • absolute and relative cluster power
    • delay
    • cluster spreads

Thank you!