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dtv group
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System Level Simulation Structure for Hybrid Networks

Background

- System level simulator for hybrid networks
- Framework: COST Action 2100 SIG Hybrid Cellular and Broadcasting Networks
  - http://www.cost2100.org/ - Pervasive Mobile & Ambient Wireless Communications
- Currently the system is developed by UTU and Polytechnic University of Valencia
  - Other participants in SIG: **Braunschweig Technical University**, University of Novi Sad and Åbo Akademi University
  - Focus is currently in DVB-H
    - Results easily extended to any transmission system

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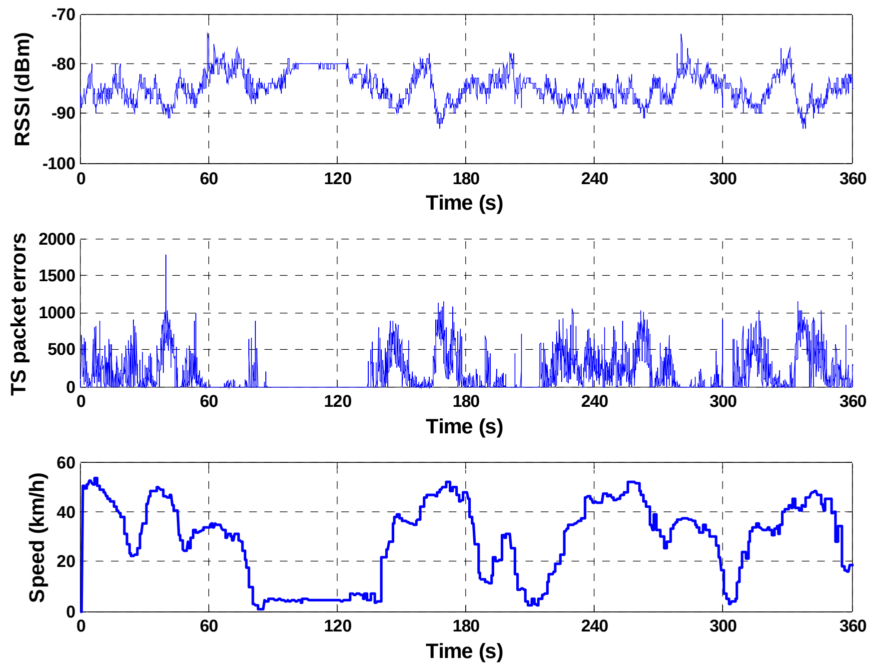
Introduction: System Modeling of DVB-H

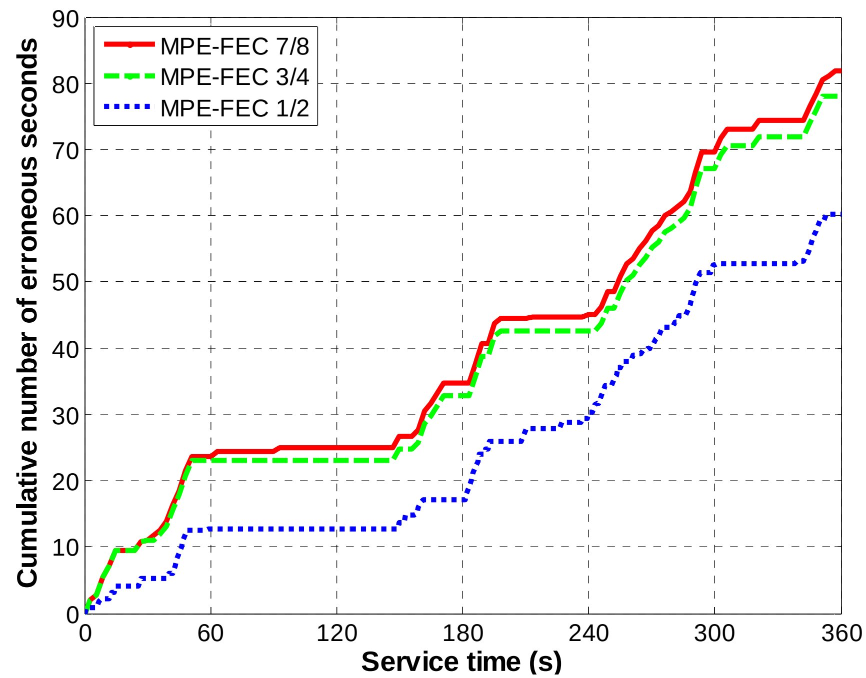
- Traditional analysis approach for broadcast networks is static
  - e.g. area coverage level
- Mobile broadcasting networks such as DVB-H require dynamic analysis
  - Quality of service (QoS) perceived by a user depends on the time-dependent error behavior of the system
- DVB-H Dynamic System Simulations
  - Allow estimating the overall system performance for mobile users dynamically over time
  - QoS aspects:
    - QoS of a video streaming service experienced by the users
    - Optimum transmission configuration for file delivery services

Example: DVB-H Field Measurement

Celtic Wing TV - vehicular measurement



Streaming service @ 256 kb/s

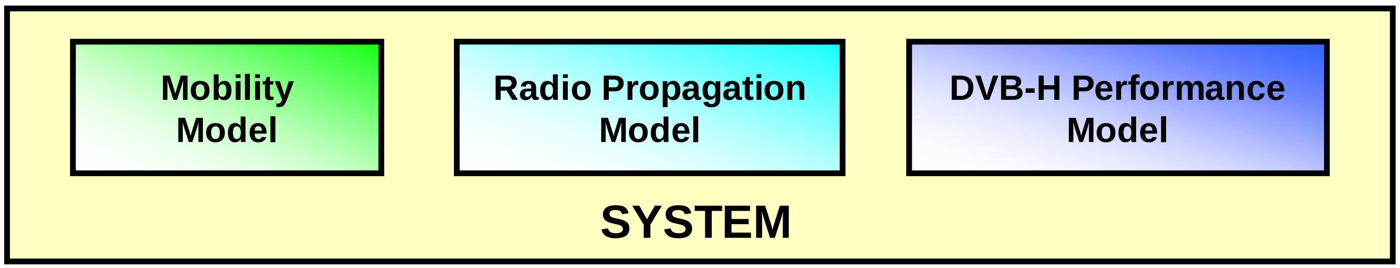


- Improvement will be perceived by users by strengthening MPE-FEC coding
- Subjective quality analysis is still largely an open problem

Overall system performance? → Large number of independent measurements needed! → Dynamic system level simulations

Objective: Dynamic System Level DVB-H Simulator

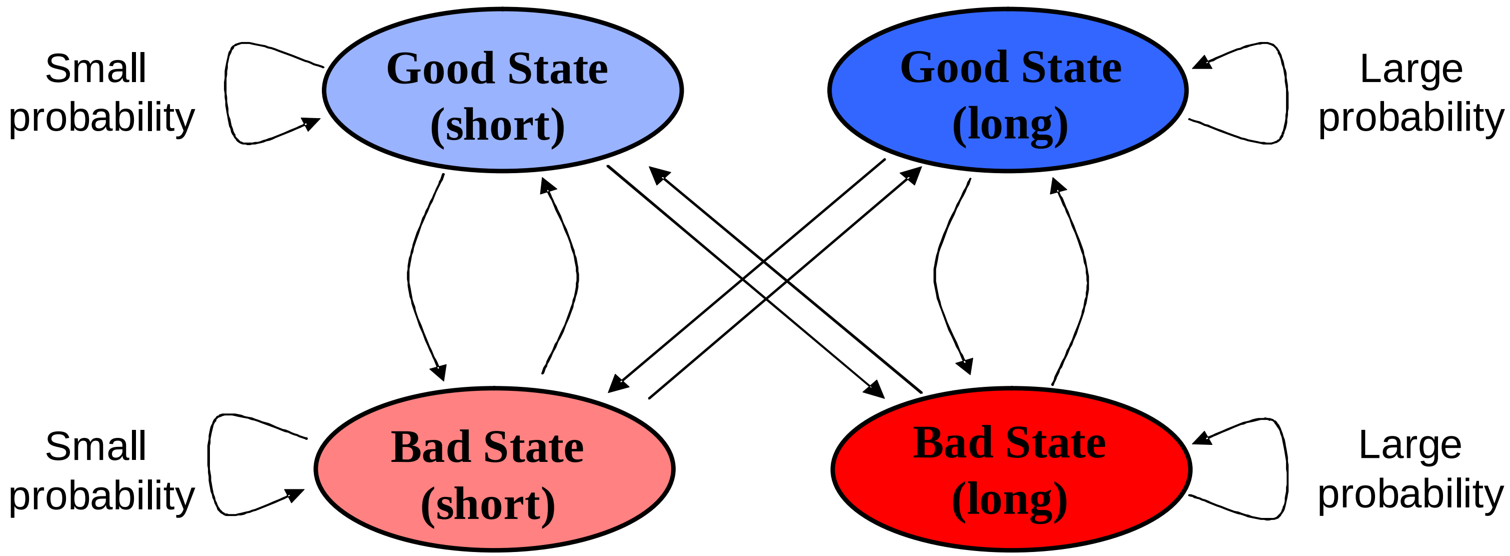
Simulates a large number of users moving simultaneously within the broadcast network and computes the packet error process perceived by each user



- Mobility model
  - Moves users across the service area and provides the user velocity when receiving a burst
- Radio propagation model
  - Computes the average CNR per user during the reception of a burst (alternatively a coverage map can be pre-computed)
- DVB-H performance model
  - Computes which data packets in the burst are correctly received for each user using the velocity and CNR information

DVB-H Physical Layer Performance Model

- Aggregated (renewal) Markov processes are used to approximate the MPEG-2 TS packet error process of the physical layer of DVB-H
- The model parameters are estimated as functions of the instantaneous received signal strength and speed of the receiver



Conceptual state diagram of a four-state error model

DVB-H Physical Layer Performance Model

- The model states are classified into two groups corresponding to correct and erroneous reception of TS packets
- The model structure is selected to ensure simple parameter estimation
  - Specific conditions are set on the state transition probabilities to impose the renewal property on the model output run length processes
  - For a given output symbol, lengths of sequences of consecutive symbols (runs) will be independent and identically distributed
  - The run length distributions are fitted to measurements

DVB-H Physical Layer Performance Model

- The following statistics are required to calculate the model parameters:
  - Probability of packet error
  - Mean length of sequences of correctly received packets
  - Mean length of sequences of erroneously received packets
  - Corresponding variances
- The model parameters are solved using the method of moments (MM) with measured error traces

For details, see:

[J. Poikonen, "Parameterization of Aggregated Renewal Markov Processes for DVB-H Simulations," *Proc. PIMRC'07*, Athens, Greece, September 2007.]

$$P = \begin{pmatrix} \alpha_1 & 0 & (1-\alpha_1)w_3 & (1-\alpha_1)w_4 \\ 0 & \alpha_2 & (1-\alpha_2)w_3 & (1-\alpha_2)w_4 \\ (1-\alpha_3)w_1 & (1-\alpha_3)w_2 & \alpha_3 & 0 \\ (1-\alpha_4)w_1 & (1-\alpha_4)w_2 & 0 & \alpha_4 \end{pmatrix}$$

$$p_E = \frac{w_3}{(1-\alpha_3)\left(\sum_{k=1}^{4}\frac{w_k}{1-\alpha_k}\right)} + \frac{1-w_3}{(1-\alpha_4)\left(\sum_{k=1}^{4}\frac{w_k}{1-\alpha_k}\right)}$$

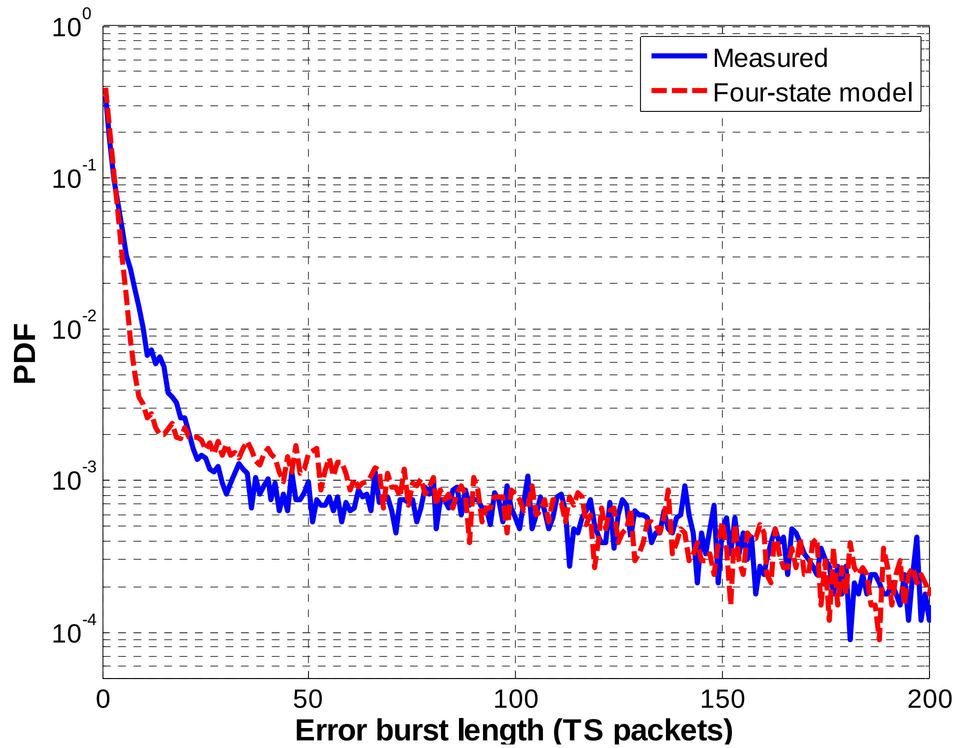
$$\mu_C = \frac{w_1}{1-\alpha_1} + \frac{(1-w_1)}{1-\alpha_2} \qquad \mu_E = \frac{w_3}{1-\alpha_3} + \frac{(1-w_3)}{1-\alpha_4}$$

$$\sigma_E^2 = \frac{w_3\alpha_3(1-\alpha_4)^2 + w_4\alpha_4(1-\alpha_3)^2 + w_3w_4(\alpha_4-\alpha_3)^2}{(1-\alpha_3)^2(1-\alpha_4)^2}$$

$$\sigma_C^2 = \frac{w_1\alpha_1(1-\alpha_2)^2 + w_2\alpha_2(1-\alpha_1)^2 + w_1w_2(\alpha_2-\alpha_1)^2}{(1-\alpha_1)^2(1-\alpha_2)^2}$$

DVB-H Physical Layer Performance Model

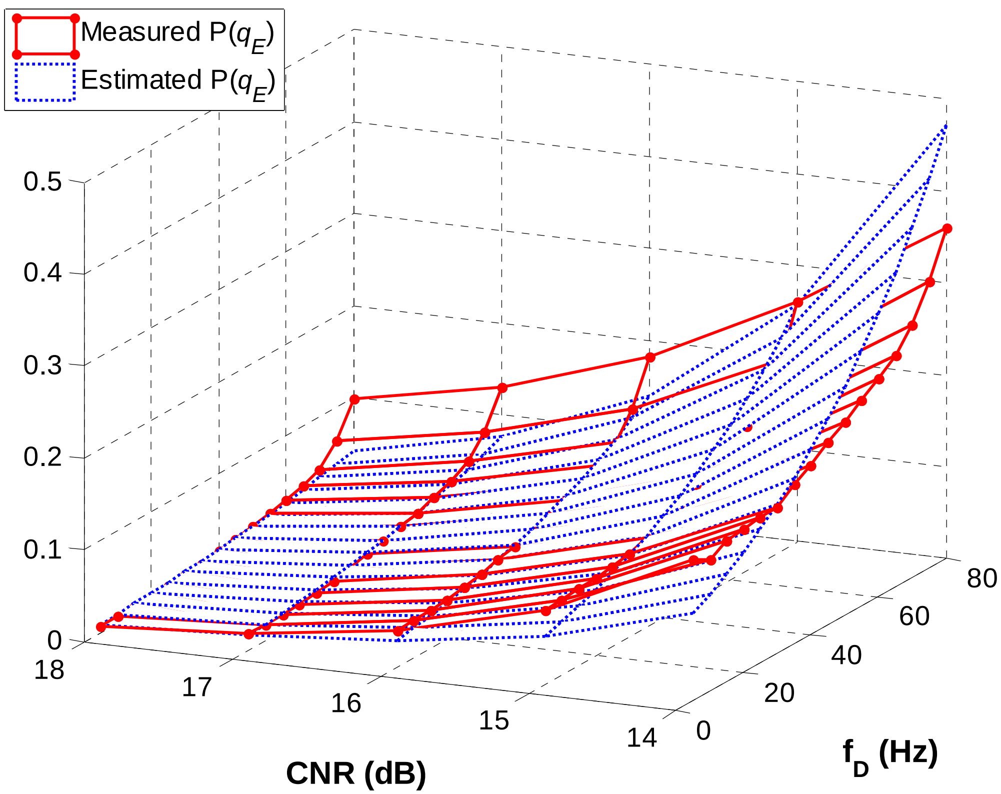
- The probability distributions for sequences of consecutive output symbols are geometric mixture distributions
  - Effectively, application of the MM results in the lengths of the model output sequences fitting the "head" and "tail" slopes of burst distributions of measured error traces



Sample distribution of error burst lengths of the four-state model fitted to a measured error trace

DVB-H Physical Layer Performance Model

- The packet error statistics necessary for determining the model parameters are approximated using laboratory measurements with a TU6 channel model
- Least squared error estimates of the relevant statistics are obtained as functions of the CNR and Doppler frequency



$$\tilde{m} = \exp(c_{1_m}\rho + c_{2_m} f_D + c_{3_m})$$

TABLE I

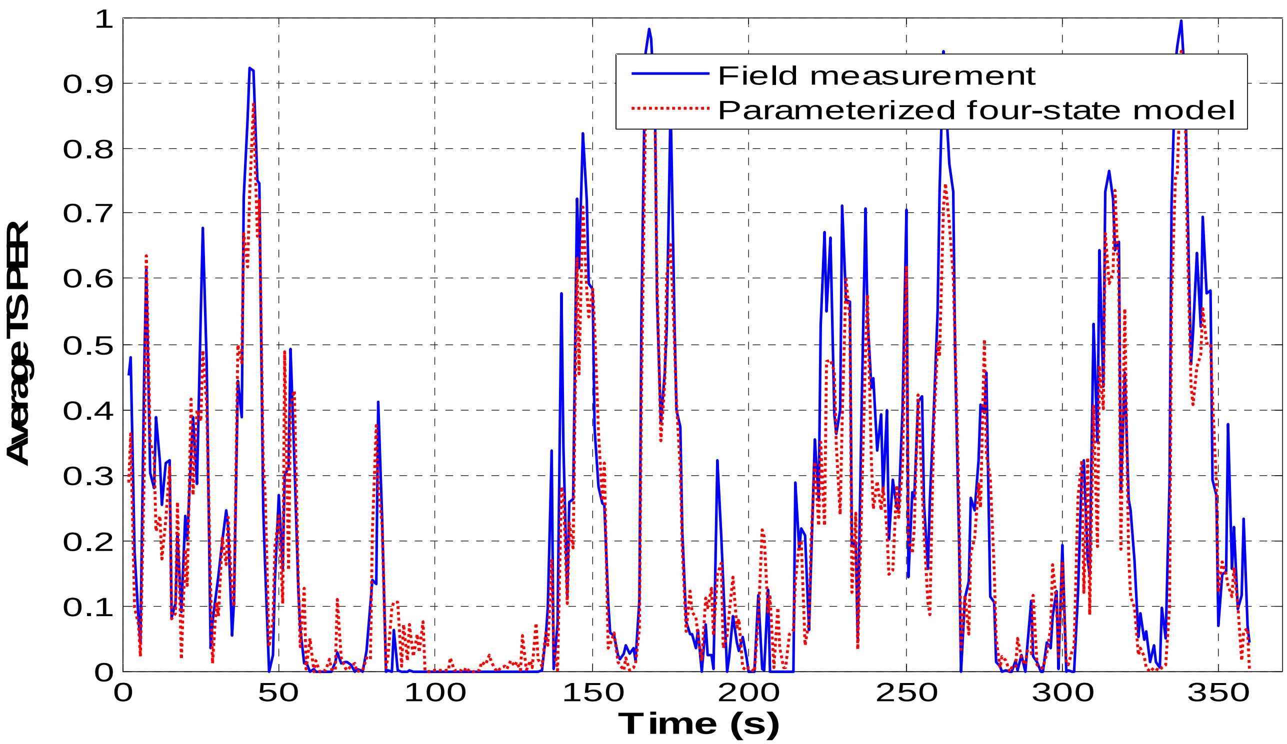
LSE COEFFICIENTS

	$P(q_E)$	$\overline{L}_E$	$\overline{L}_C$	$S^2_{L_E}$	$S^2_{L_C}$
c_{1_m}	−0.6068	−0.1288	0.5295	−0.3480	1.0460
c_{2_m}	0.0213	−0.0020	−0.0252	−0.0312	−0.0742
c_{3_m}	6.0409	4.7484	−2.1428	12.7709	−1.9695

Approximating the packet error statistics of lab measurements

Measurement-based dynamic simulation

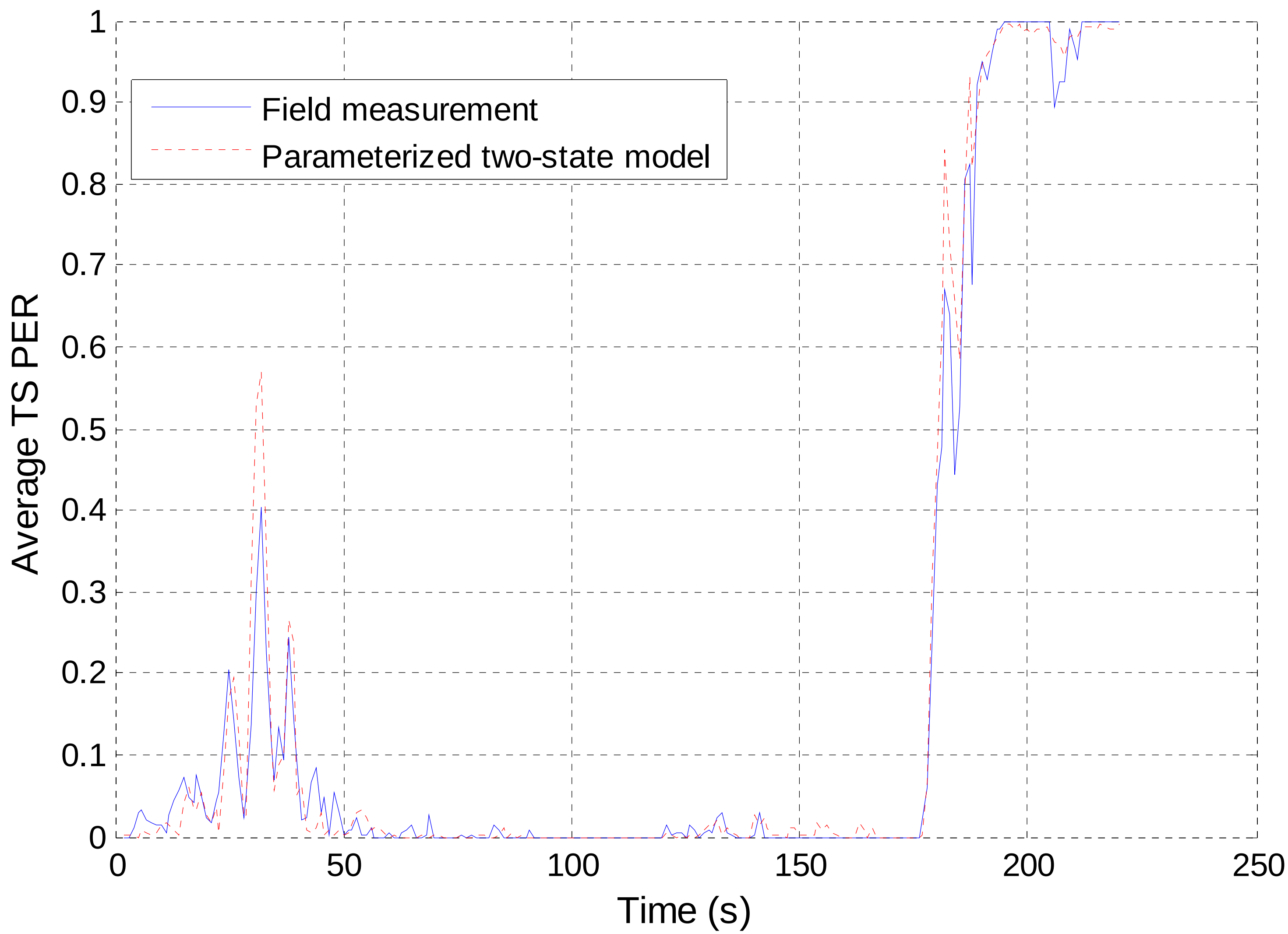
- The DVB-H performance model is initially verified by replacing the mobility and radio propagation models with measured RSSI and vehicle speed values
- The simulation results thus obtained are compared to measured TS packet error behavior



[%]	Meas.	Model.
TS PER	23.4	23.7
MFER	28.1	29.6
IP PER	21.0	20.5

TS packet error simulation based on measured RSSI and vehicle speed (The Hague)

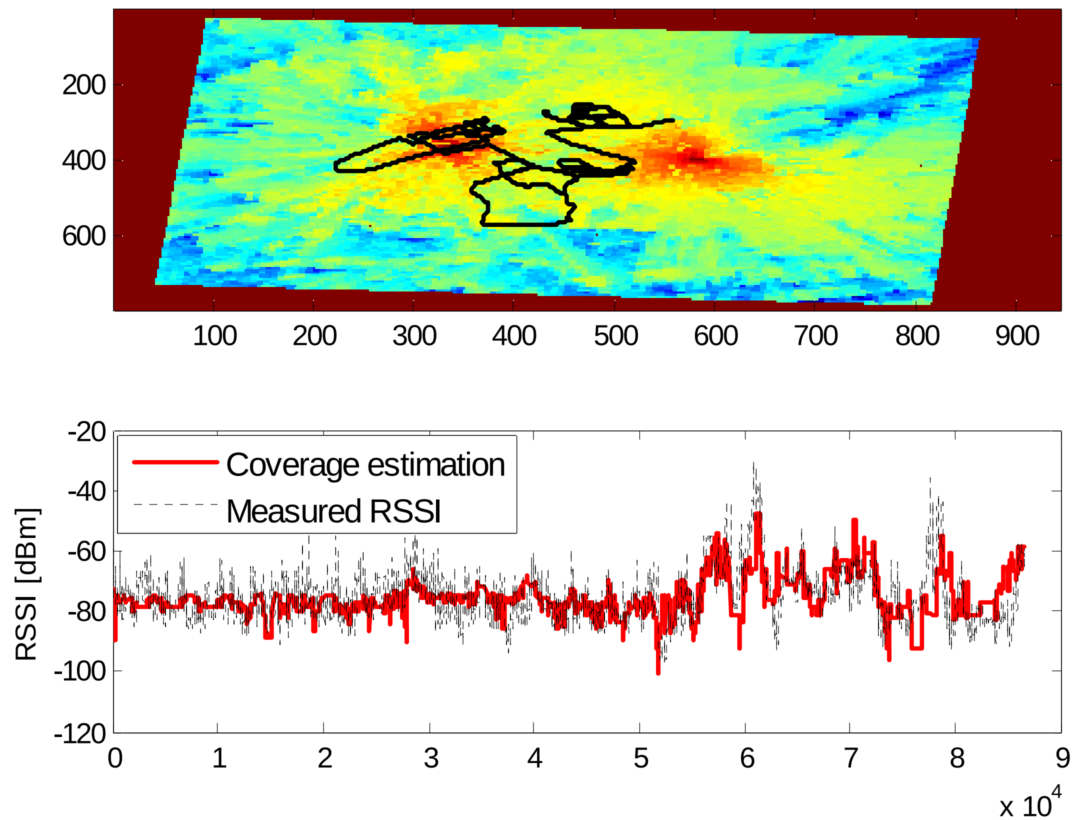
Measurement-based dynamic simulation



TS packet error simulation based on measured RSSI and vehicle speed (Turku)

From measurement-based to prediction-based dynamic simulation

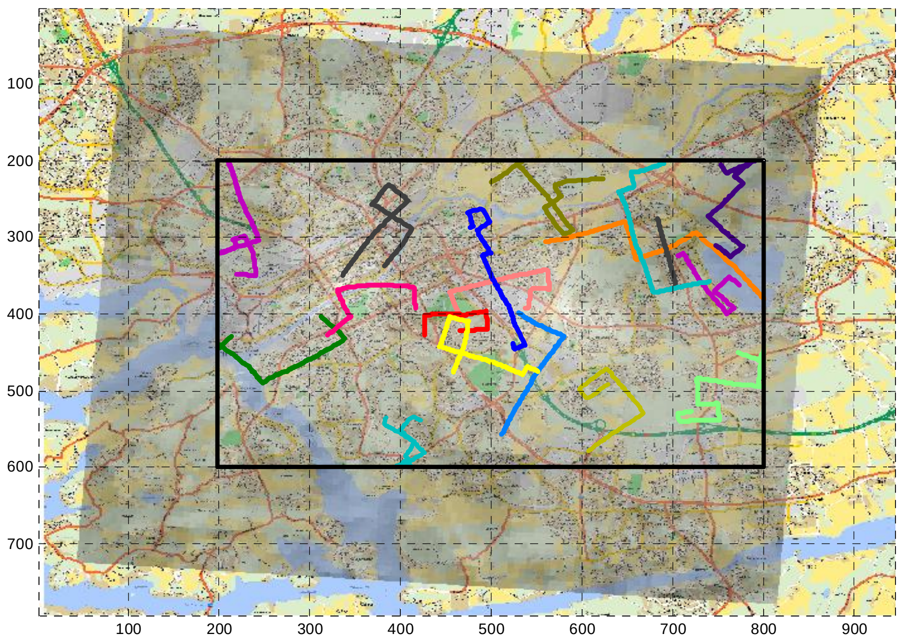
- The next step is to apply the physical performance model using coverage prediction instead of measured RSSI values
- Simulation results will depend on the accuracy of the coverage map
  - Careful verification of the prediction should be performed
  - This requires extensive measurements
- Prediction verification is still an ongoing activity for this study

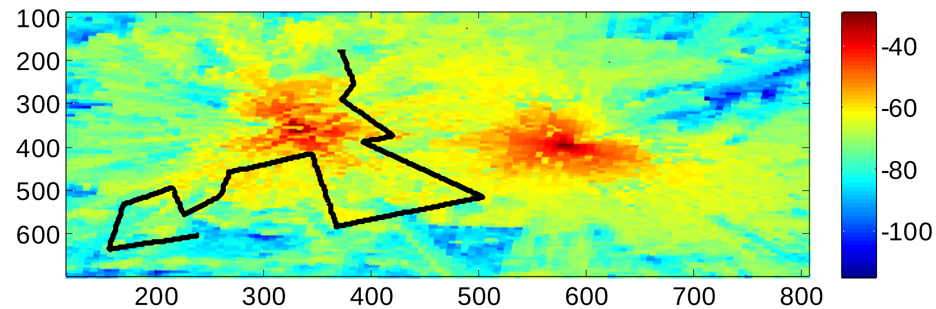


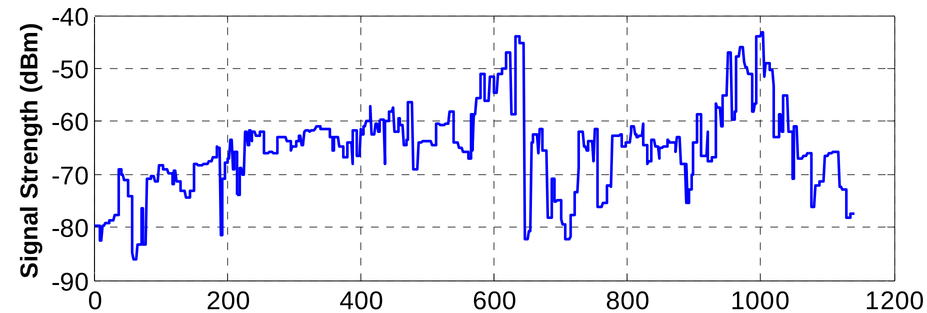
Estimated and measured signal strengths vs. receiver location

Coverage prediction-based dynamic simulation

- Assuming the coverage map to be sufficiently accurate, we proceed to simulate random receiver trajectories within the coverage area
- A mobility model is implemented to generate an arbitrary number of receivers moving within the coverage area. Corresponding signal strength estimates are then obtained from a precalculated coverage prediction map.

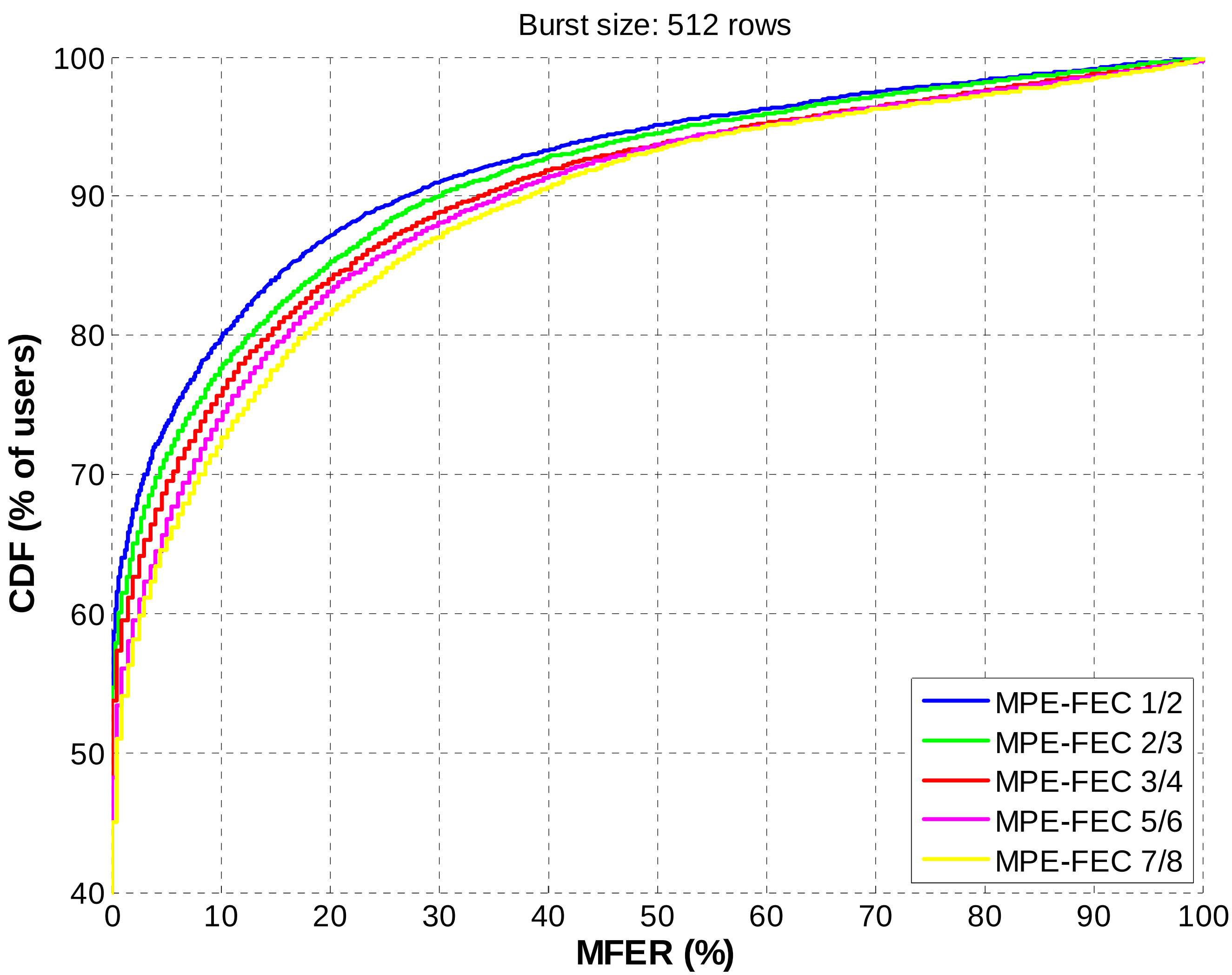






Left: coverage map and small set of receiver trajectories from the mobility model.
Right: one random receiver route and signal strength approximation

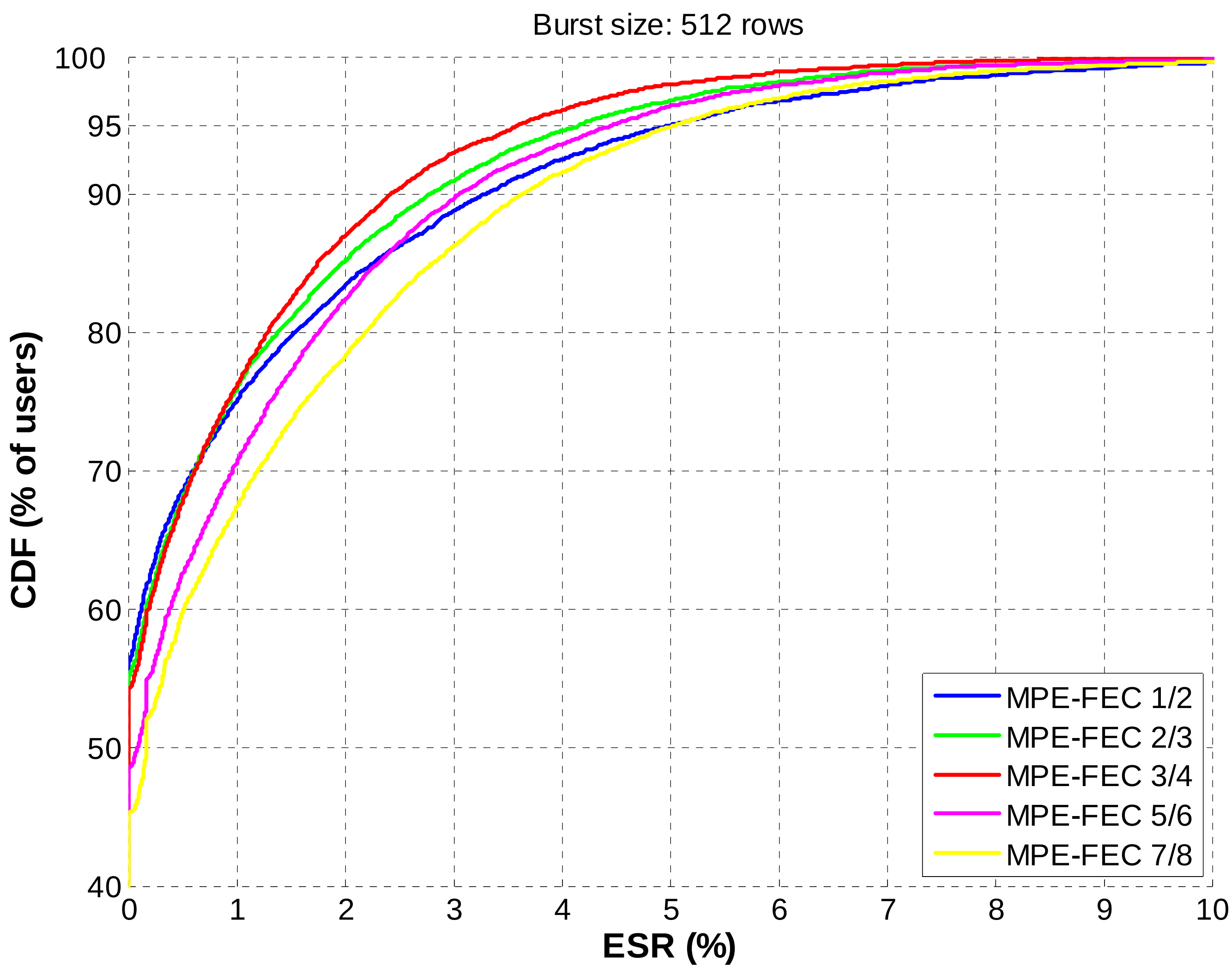
Simulation example and initial results



In this simulation example, it can be seen that on average, about 70% of users within the coverage area experience an MPE-FEC Frame Error Ratio less than 5%, which is a typical error criterion used for DVB-H.

MPE-FEC Frame Error Rate distribution for 10 000 mobile receivers

Simulation example and initial results



However, over 95% of the same users experience an Erroneous Seconds Ratio (ESR) less than 5%. This emphasizes the importance of suitable error criteria for analyzing the dynamic performance of the system.

Erroneous Seconds Ratio distribution for 10 000 mobile receivers

Future Work

- Further verify accuracy needed of the velocity model and coverage estimation
- Add UMTS models to the system
  - Possible research topic: Packet retransmission via 3G for DVB-H packet errors
- Adding more transmission systems (WLAN, WiMax, eg.) requires physical propagation models or equipment capable of storing packet error information
- Current considered applications
  - Optimum DVB-H transmission configuration
  - RRM in Hybrid cellular and DVB-H networks

Summary

- The simulator will enable to emulate the actual QoS of a DVB-H service (both streaming and file download) perceived by a user moving across the service area.
- It should be possible to define specific trajectories to be compared with measurements to tune the simulator, or just to check the QoS for some specific routes.
- The simulator will be especially useful to get the average QoS perceived by the users, which can be used to optimize the transmission configuration.
- Could be integrated into propagation and planning tools? Would be able to provide more detailed information about user experience.
- Work may be integrated with other (upcoming) projects about more realistic error criteria for video streaming.

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