Predicting CSI for Link Adaptation employing Support Vector Regression for Channel Extrapolation

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***Abstract*—Link adaptation in LTE-A is based on channel state information (CSI). For time-selective channels, CSI might be outdated already in the next subframe. Hence, CSI prediction must be employed. This paper investigates support vector regression (SVR) for channel estimation/prediction. SVR is applied for learning from the previous channel estimates in order to extrapolate/predict the CSI. The simulation results show that the proposed method performs better than conventional interpolation/extrapolation methods especially in a reasonable signal to noise ratio regime and at low to medium user speeds.**

***Keywords*—Support Vector Machines, Channel Estimation, LTE, MMSE, interpolation, extrapolation, CSI prediction**

I. Introduction

The most recent standards for wireless cellular networks employ Orthogonal Frequency Division Multiplexing (OFDM) as multiple access technique. In such systems, the data rate of each user is defined by adaptive modulation and coding (AMC) according to the channel state. In Long Term Evolution (LTE) downlink (DL) the User Equipment (UE) feedbacks the quantized CSI while in the uplink (UL) transmission, the Base Station (BS) can directly estimate the UE channel. To work with non-quantized channel estimates, we restrict ourselves to the UL. Then, the BS performs link adaptation which results in a delay due to the time taken by the physical layer to process the information. The 3GPP reports a delay of at least 5 ms [1].

Few research has been published regarding the process delay effect such as [2], in which the authors proposed a cubic spline extrapolation to obtain a prediction horizon that allows extending the reliability of the channel quality evaluation along time. However, they did not show the limit of their prediction in terms of time-selectivity. To address this issue, we will investigate the performance of various interpolation methods in an LTE-A compliant environment using the Vienna LTE-A Link Level Simulator [3] and extend it for extrapolation. The present study follows the approach of [4] which uses support vectors regression (SVR) to perform channel interpolation.

SVR is related to statistical learning theory [5] and it became popular because of its success in handwritten digit recognition. Hence, it has been investigated in different areas and recently has been applied for interpolation in LTE channel estimation [4], [6], [7], both in UL and DL. It has been shown in [4] that SVR interpolation for channel estimation in LTE outperforms spline and linear interpolation.

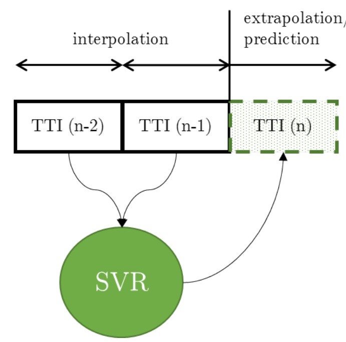

Fig. 1: Interpolation and extrapolation/prediction.

The rest of the paper is structured as follows. Section 2 shows the Bit Error Ratio (BER) and the Mean Square Error (MSE) results under zero delay to which we refer to as interpolation. SVR outperforms spline interpolation and comes close to perfect channel knowledge, even at high speed. In Section 3, we present the effect of process delay on UE performance in the LTE UL. We predict the channel by means of extrapolation based on the SVR model, trained by previous channel estimates. Section 4 provides a preliminary conclusion and the outlook for the full paper.

II. SVR Interpolation

In this section, we compare SVR with the conventional interpolation methods such as spline[1]. Our simulations are based on the parameters shown in Table I.

We consider a single antenna transmission on LTE uplink. Sounding reference symbols (SRS) are not considered. We employ demodulation reference signals to perform both interpolation and extrapolation. Extrapolation is also referred to as prediction in the rest of the paper, c.f., Figure 1. To compare the performance of interpolation methods we use the uncoded BER and MSE as metrics. We conduct the simulations under different UE speeds at fixed Signal to Noise Ratio (SNR) to get the MSE performance as shown in Figure 2.

We can see from the figure that SVR interpolation is sensitive to speed, thus, to inter carrier interference (ICI).

[1]We choose spline only for comparison since it has been shown in [3] that spline and linear have almost same performance at three interpolation points and above.

TABLE I: Simulation Parameters

Parameter	Value
System bandwidth	1.4 MHz
Number of subcarriers N_{SC}	72
Process delay	0 TTI / 1 TTI
Channel model	Typical Urban (TU)
Antenna configuration	1×1 uplink
Receiver	MMSE
Channel estimator	MMSE
Modulation scheme	4-QAM
UE speed	10 – 100 km/h

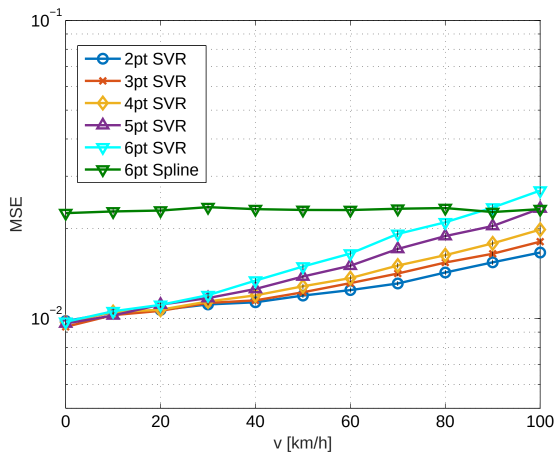

Fig. 2: Channel estimation and interpolation error at 7dB SNR.

The BER performance in Figure 3 clearly shows that SVR outperforms other schemes especially at low SNR. The saturation point is not fully understood and will be subject of further investigation.

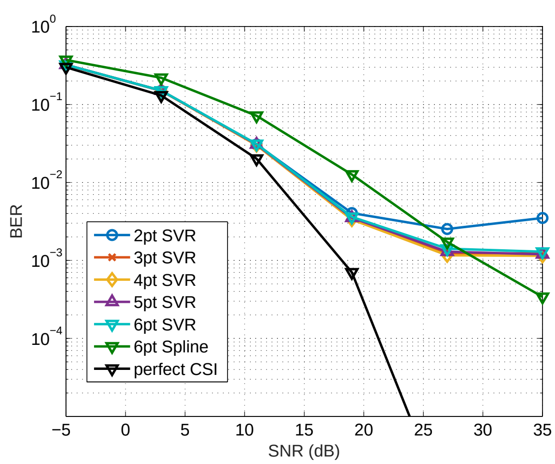

Fig. 3: Uncoded BER for interpolation at 100km/h.

III. SVR Extrapolation

As demonstrated in Section 2, SVR outperforms the spline and linear interpolation with a margin of 5 dB, we decided to investigate the performance of SVR for extrapolation. In other

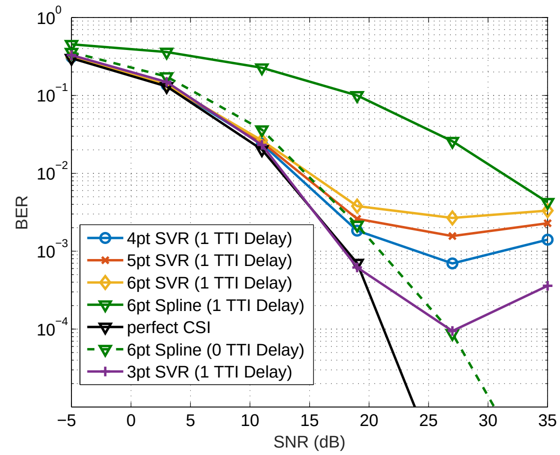

Fig. 4: Uncoded BER for extrapolation at 10km/h.

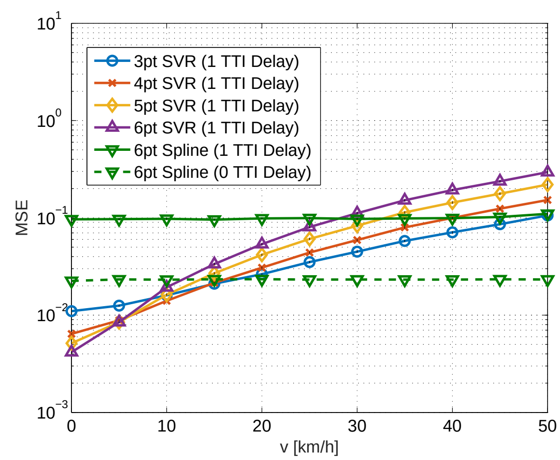

Fig. 5: Channel estimation and extrapolation error at 7dB SNR.

words, we assume a delay of 1 transmission time interval (TTI) and based on the previous subframes we predict/extrapolate the channel in the current subframe. As shown in Figure 4. SVR with 1 TTI delay (1 ms) outperforms spline for extrapolation (the purple curve) and it gives even better performance compared to spline with 0 TTI delay (dashed curve), until 26 dB SNR.

In order to investigate the speed limit of the proposed SVR prediction, we set the SNR to 7 dB and investigate the MSE performance for different UE velocities as shown in Figure 5. We can clearly see that SVR prediction with 1 TTI delay outperforms spline with 0 TTI delay for UE speeds up to 20 km/h and it outperforms spline with 1 TTI delay for UE speeds up to 50 km/h. We can also see that more previous points we have for SVR extrapolation will help improve the prediction at low speed. However, it distort the learned model at higher speeds. Hence, it results in performance degradation because of time-selectivity. This effect is observed also for interpolation in Figure 2.

IV. Preliminary Conclusion and Full Paper Outlook

A. Conclusions

For an LTE-A uplink transmission model we investigated the performance of SVR for interpolation. It has been shown that SVR performs better than other schemes. Therefore, we propose to use SVR for extrapolation allowing 1 TTI delay. Doing so, it has been shown that SIR predicted channel performs as good as spline based methods applied for 0 TTI delay until 26 dB SNR and a maximum speed of 20 km/h. The results obtained are very promising for improving the performance of channel estimation in case of link adaptation process delay.

B. Full Paper Outlook

For the full paper we will investigate the process delay more deeply by introducing higher process delay and we will use throughput (spectral efficiency) as another method to compare various settings. Also, we will analyze the maximum process delay to reach a certain spectral efficiency threshold.

Further, necessary adaptations for MIMO transmissions and restrictions on frequency hopping will be explained.

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