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Agenda Item:	AH24: High Speed Downlink Packet Access
Source:	**Wiscom Technologies**
Title:	On the Need of Long-Range Prediction (LRP) of Channel Estimation in HSDPA and Text Proposal
Document for:	Discussion and Decision

1 Introduction

The simulation results regarding the effect of channel estimation error on the link level and system level performance of HSDPA showed [1,2,4,5,6] that the link level and system level performance is very sensitive to the channel estimation (used for channel phase and other purposes) and thus the accurate channel estimation is essential, especially in the situation of higher modulation, Turbo code and high vehicle speed. The need of LRP of channel estimation has fundamental impact on limitation of HSDPA in terms of peak data rate and vehicle speed. Follwowing [7] we are proposing an approach to improve system perforamnce including throughput and the peak data rate and also enable HSDPA [4] to be used for higher vehicle speeds.

The idea of a communication system where the transmitter has the side information feedback from receiver to transmitter was traced back at least to Claude E. Shannon as early as in the 1950s. Channels with feedback from the receiving to the transmitting point are special case of a situation in which there is additional information available at the transmitter which may be used as an aid in the forward transmission system. Along with this line, a lot of ideas such as adaptive transmission techniques appeared to solve the problems in the fading channel.

2 Performance Bounds

For the QAM we can get upper and lower performance bounds. For square-QAM, carrier regeneration using pilot-aided signal is essential. When we apply Gray encoding with absolute phase coherent detection. the lower bound of BER for Gray-encoded 16QAM and 64QAM is in AWGN given by

$$\begin{aligned} P_{e16QAM} \; ? \; \tfrac{3}{8} erfc(\sqrt{\tfrac{2}{5} ?_b}) \; ? \; \tfrac{9}{64} erfc^2 (\sqrt{\tfrac{2}{5} ?_b}) \\ P_{e64QAM} \; ? \; \tfrac{7}{24} erfc(\sqrt{\tfrac{1}{7} ?_b}) \; ? \; \tfrac{49}{384} erfc^2 (\sqrt{\tfrac{1}{7} ?_b}) \end{aligned} \quad (1)$$

For Rayleigh fading channel, we have the upper bound

$$P_{e16QAM} \;?\; \frac{3}{8} \;?\; 1 \;?\; \frac{1}{\sqrt{1 \;?\; \frac{5}{2?_b}}} \;?$$

$$P_{e64QAM} \;?\; \frac{7}{24} \;?\; 1 \;?\; \frac{1}{\sqrt{1 \;?\; \frac{7}{?_b}}} \;? \qquad (2)$$

From (1) and (2), clearly we should try our best to approach the lower bound (1) (for the perfect channel estimation and fading compensation) with the aid of the channel estimation. This bound motivates the study of this contribution using a novel technique called Long Range Prediction (LRP). The scope of this study in channel estimation and prediction includes not only link level issues like the modulation and coding but also the system issues like ARQ and antenna diversity.

3 Principle of Long-Range Prediction (LRP)

In WCDMA, several adaptive transmission techniques, including adaptive modulation and coding, power/rate control, antenna diversity, ARQ, and others, are used for adaptation to rapidly time variant fading channel conditions. Since the channel changes rapidly, the transmitter and receiver are usually not designed optimally for current channel conditions and thus fail to take advantage of the full potential of the wireless channel. By exploiting the time-varying nature of the wireless multipath fading channel, all these adaptive schemes are trying to use power and spectrum more efficiently to realize higher bit-rate transmission without sacrificing the bit error rate (BER) performance. To implement the adaptive transmission methods, the channel state information (CSI) often may be available at the transmitter. CSI can be estimated at the receiver and sent to the transmitter via a feedback channel. Feedback delay, overhead, processing delay and etc are considered. For very slowly fading channels (pedestrian or low vehicle speed for most HSDPA applications), outdated CSI is sufficient for reliable adaptive system design. For faster vehicle speed, we need LRP in order to realize the potential of adaptive transmission methods. These channel variations have to be reliably predicted at least several milliseconds (ms), or tens to hundreds of data symbols. Notice that one frame (15 slots) of WCDMA is 10 ms. The goal of LRP is to enable the adaptive transmission techniques.

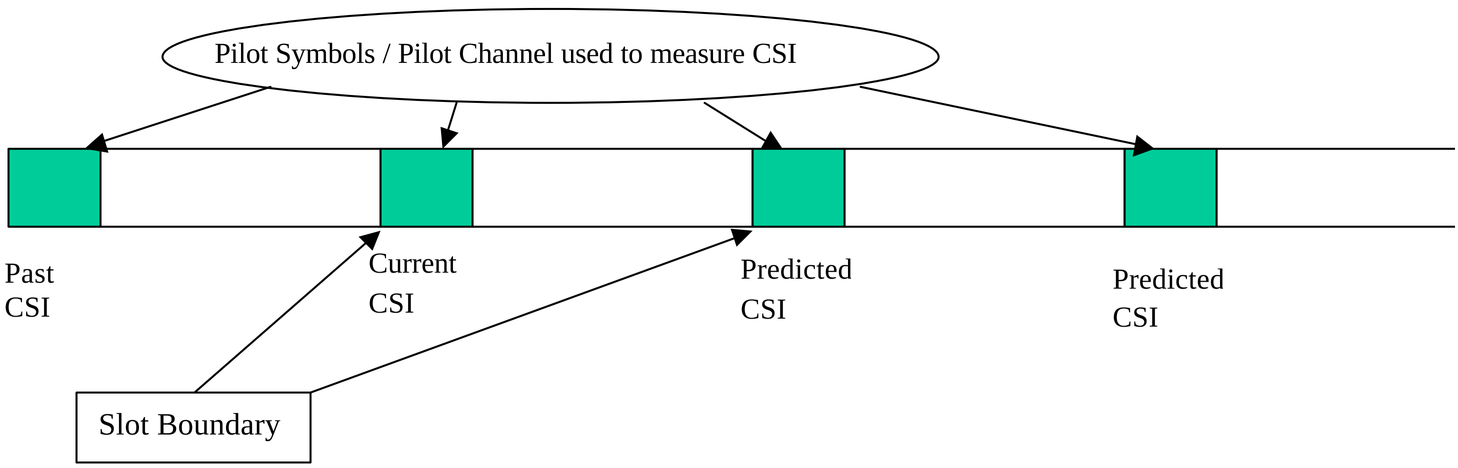

Fig. 1 The Channel State Information (CSI) is obtained using either time-multiplexed pilot symbols (transmitted in DPCCH) or code-multiplex pilot channel signals (transmitted in CPICH).

4 Use of LRP for HSDPA

Many studies have addressed estimation of current fading conditions, prediction of future fading conditions through LRP has not been addressed until recently. In this contribution, following [7] we continue to use this new tool to improve the performance of WCDMA, especially for HSDPA applications. As shown in Fig. 2 and Fig. 3 we proposed a novel WCDMA system paradigm that uses the mechanisms of prediction of future fading conditions. The spirit and principle of this system paradigm can be used for other system design such as CDMA2000, TDD. Our major contribution is to study how the proposed new system paradigm through LRP will improve the WCDMA system performance, especially high speed packet access, including

1. Predictive/Adaptive modulation
2. Predictive/Adaptive channel coding/Turbo coding
3. Predictive/Adaptive transmitter diversity
4. Predictive/Adaptive ARQ
5. Predictive/Adaptive Scheduling
6. Predictive/Adaptive Cell Site Selection
7. Predictive/Adaptive Multi-Code
8. Predictive/Adaptive Multiple Input and Multiple Output (MIMO) Antenna Processing.

An intuitive justification of use of LRP for HSDPA is the sensitivity of the above techniques to the fading CSI. We know from a lot of other studies in different branches that "knowing" or predicting the fading CSI reduces the error of channel estimation, thus improving the performance of the system in both link level and system level. The link level performance has been confirmed in [1,2,4,5] where the channel estimation error of 2% relative to the channel power seems to block the link level performance of HSDPA for high vehicle speed (e.g. 30 kmh). We also observed [5] for fixed feedback MCS selection delay, the channel measurement accuracy can lead to 2 dB performance loss. This suggests more advanced MCS selection rule to improve AMCS and HARQ performance. The reason for the above results is that high-level QAM and Turbo code are very sensitive fading CSI. Turbo code can be used for transmitting high-speed CDMA data since the CDMA channel is closer to the complex Gaussian noise in the multipath fading channel.

On the other hand, higher modulation has a potential to achieve a high bit rate and a high spectral efficient system, BUT it depends on the anti-fading compensation techniques, non-linear compensation techniques, and the service demand. Another difficulty of channel estimation for QAM is the need for amplitude variation. In the M-ary QAM, a symbol is generated according to $\log_2 M$-bit of the source data. Because coherent detection is essential for square -QAM (that has been proposed in HSDPA [4]), carrier regeneration using pilot signal-assisted schemes (CDM in CPICH or TDM DPCCH)) is necessary for M-ary QAM. It is well known that QAM is sensitive to fading CSI. Thus any improvement in fading CSI will convert into gains in techniques such as Turbo code and QAM.

A critical fact is that the transmission efficiency under flat Rayleigh fading conditions with smaller maximum Doppler frequency f_d is higher than that AWGN channel conditions because long error-free length is more probable under fald Rayleigh fading conditions with smaller f_d than under AWGN channel conditions due to burstness of the error sequence. This is one of reasons to justify ARQ or Hybrid ARQ in HSDPA. This fact also implies that "knowing" f_d in advance of one future frame or future 10-15 slots/sub-frames, say, by means of LRP, seems to increase the transmission efficiency of a system with ARQ under flat Rayleigh fading channel conditions [6]. In [6] we confirmed that the MCS selection delay is likely to cause about 1 dB performance loss. In addition when f_d increases, transmission efficiency decreases because error-free length becomes short with increasing f_d. Obviously we find transmission efficiency depends on bit energy E_b/N_0.

Scheduling of resources benefits from the knowing the future fading CSI and tries to avoid the transmission when channel is not in good conditions. The proposed technique will help reduce the scheduling delay and improve the throughput.

Although space diversity is a very effective technique for compensating for rapid fading, it is helpless to compensate for log-normal fading or path loss due to distance. This requires so-called site diversity to obtain independent diversity paths by using plural base stations. In the case of Fast Cell selection, the UE selects the best cell every frame from which it wants to receive data on the HS-DSCH. HS-DSCH data is then transmitted to the UE from this cel only. UE can better select the best frame once UE knows the future fading CSI.

If we know the fading CSI, we can adaptively adjust the use of multi-code. MIMO Multiple antennas seem to be sensitive to the fading CSI. The improved performance of LRP used for the fading CSI will definitely help MIMO antenna processing.

5 Simulation Results

To support the claims in the Sections 3 and 4, we performed a lot of simulations using our simulation platform that was calibrated against others [1,2]. So far we investigated the benefit of using LRP by studying both the link level and system level performance.

In the work [1,2], we presented the link simulations that were collected into the HSDPA Technical Report [4]. The results show that the link level performance of higher order modulation is very sensitive to the channel estimation (used for channel compensation and other purposes) and thus accurate channel estimation is essential, especially at high vehicle speeds. In [5] we presented the simulation results of AMCS and HARQ for HSDPA in the non-ideal measurement and feedback situations assuming the fixed MCS selection delay. For the typical value of Ec/Ioc, the channel measurement accuracy has large impact on the throughput, i.e. up to 2 dB loss compared with the ideal case measurement and feedback defined in [5]. It suggests that at slow vehicle speed, longer time CPICH average might be necessary for more accurate measurement to improve the throughput. However, at fast vehicle speed, the long time average might fail to track the channel condition closely. Thus, more advanced MCS selection rule might include both long term and short term channel average as well as Doppler frequency estimation to improve the AMCS and HARQ performance. Further investigation is needed in this topic. These above results verified the values of the proposed approach such as Predictive/Adaptive modulation and Predictive/Adaptive channel coding/Turbo coding.

To illustrate the value of the proposed approach for system level performance, we investigated the effect of MCS selection delay on the performance of AMCS and HARQ for HSDPA [6]. The performance loss due to the MCS delay is not significant at very slow vehicle speed. However it increases at higher vehicle speeds and larger MCS selection delays. For typical operating points, the loss due to the MCS delay can be as large as 1 dB or 22% throughput loss. Thus the technique to predict the channel condition might help to reduce such performance loss. The channel prediction technique can be incorporated with the MCS selection rule to improve the AMCS and HARQ performance in HSDPA.

6 Conclusion

Following previous work [7], we add more details about the implementation of Long Range Prediction (LRP) in HSDPA. Link level and system level simulations show that LRP can improve system performance of HSDPA in several ways. Practical implementation of LRP itself can be done in a lot of ways as suggested in [8]. Some experimental studies [8] suggest that LRP can be used to predict the fading signals as far as 10ms. We strongly believe that LRP can be practically implemented in our HSDPA.

7 Text Proposal for 3G TR 25.848

Based on the above, we have the following text proposal for 3G TR 25.848 [4]:

5 Overview of Technologies considered to support UTRA High Speed Downlink Packet Access

5.1 Adaptive Modulation and Coding (AMC)

5.2 Hybrid ARQ (H-ARQ)

5.3 Fast Cell Selection (FCS)

5.4 Multiple Input Multiple Output Antenna Processing

5.5 Long Range Prediction of Fading Siganls

"The concept of LRP is an enabling technology and can improve the performance of HSDPA in terms of system building blocks such as MCS, ARQ, scheduling, MIMO, and etc.

The concept of LRP in HSDPA should be supported as an open study issue by including the LRP concept in the TR 25.848."

6 Proposed Physical Layer structure of High Speed Downlink Packet Access

6.1 Basic Physical Structure <frame length, update rates spreading codes, etc>

6.1.1 HSDPA physical-layer structure in the code domain

6.1.2 HSDPA physical-layer structure in the time domain

6.2 Adaptive Modulation and Coding (AMC)

6.3 Hybrid ARQ (H-ARQ)

6.4 Fast Cell Selection (FCS)

6.4.1 Physical-layer measurements for cell selection in case of fast cell selection

6.4.2 Physical-layer signalling for cell selection in case of fast cell selection

6.4.3 Physical-layer signalling for transmission-state synchronisation in case of inter-Node-B FCS

6.4.4 **Conclusions**

6.5 Multiple Input Multiple Output Antenna Processing

6.6 Fast scheduling <physical layer interaction>

6.7 Associated signaling needed for operation of High Speed Downlink Packet Access

6.7.1 Associated Uplink signaling

6.7.2 Associated Downlink signaling

6.8 Long Range Prediction of Fading Signals

7 Evaluation of Technologies

7.1 Adaptive Modulation and Coding (AMC)

7.1.1 Performance Evaluation <throughput, delay>

7.1.2 Complexity Evaluation <UE and RNS impacts>

7.2 Hybrid ARQ (H-ARQ)

7.2.1 Performance Evaluation <throughput, delay>

7.2.2 Complexity Evaluation <UE and RNS impacts>

7.2.2.1 N-channel stop-and-wait H-ARQ

8 Reference

[1] Wiscom Technologies, “Influence of channel estimation on the link level performanc of HSDPA,” TSGR1#17(00) 1327, TSG-RAN Working Group 1 Meeting #17, Stocholm, Sweden, November 21-24, 2000.

[2] Wiscom Technologies, TSG-RAN Working Group 1 Meeting #17,Link Level Simulations for HSDPA, TSGR1#17(00) 1326, TSG-RAN Working Group 1 Meeting #17, Stocholm, Sweden, November 21-24, 2000.

[3]] Wiscom Technologies, “HSDPA Technical Reports text proposal on Soft Decoding Metric for Multipath Fading Channels,” TSGR1#17(00) 1394, TSG-RAN Working Group 1 Meeting #17, Stocholm, Sweden, November 21-24, 2000.

[4] 3GPP TR V0.2.0 (2000-05), Physical Layer Aspects of UTRA High Speed Downlink Packet, 3GPP Release 2000, TSG-RAN Working Group1 meeting#18, TSGR1#18(00)xxxx, Boston, Massachusetts, USA, 15th-18th Jan. 2001.

[5] Wiscom Technologies, “Performance of AMCS and HARQ for HSDPA in the non-ideal measurement and feedback situations,” TSGR1#18(01) 0051, TSG-RAN Working Group 1 Meeting #18, Boston, Massachusetts, USA, Jan. 15-18, 2001.

[6] Wiscom Technologies, “Effect of MCS selection delay on the performance of AMCS and HARQ for HSDPA,” TSGR1#18(01) 0050, TSG-RAN Working Group 1 Meeting #18, Boston, Massachusetts, USA, Jan. 15-18, 2001.

[7] Wiscom Technologies, “Use of Long-Range Prediction for channel estimation and its application in HSDPA,” TSGR1#17(00) 1393, TSG-RAN Working Group 1 Meeting #17, Stocholm, Sweden, November 21-24, 2000.

[8] A. Duel-Hallen et al, “Long-Range Prediction of Fading Signals,” IEEE Signal Processing Magazine, May 2000.

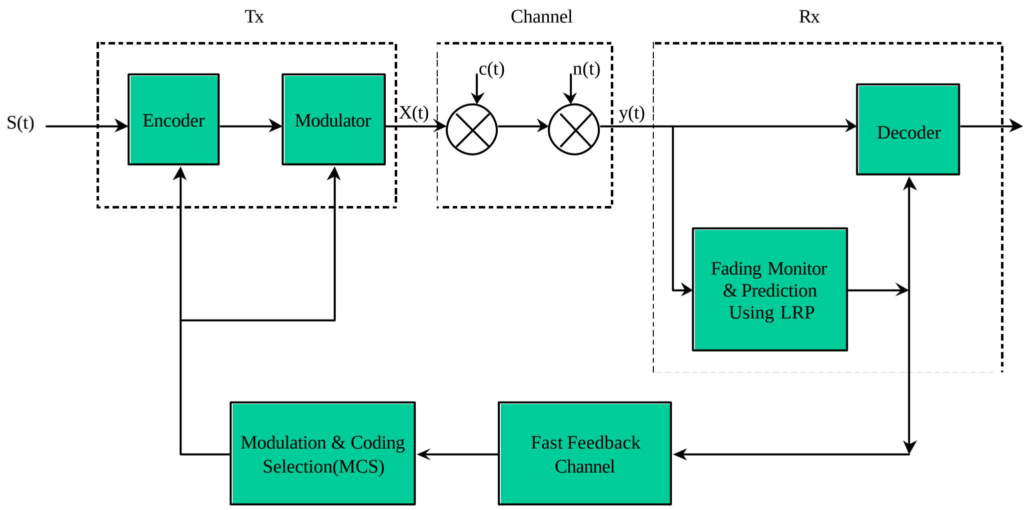

Fig.2 Illustration of Principle of Long-Range Prediction and its Application

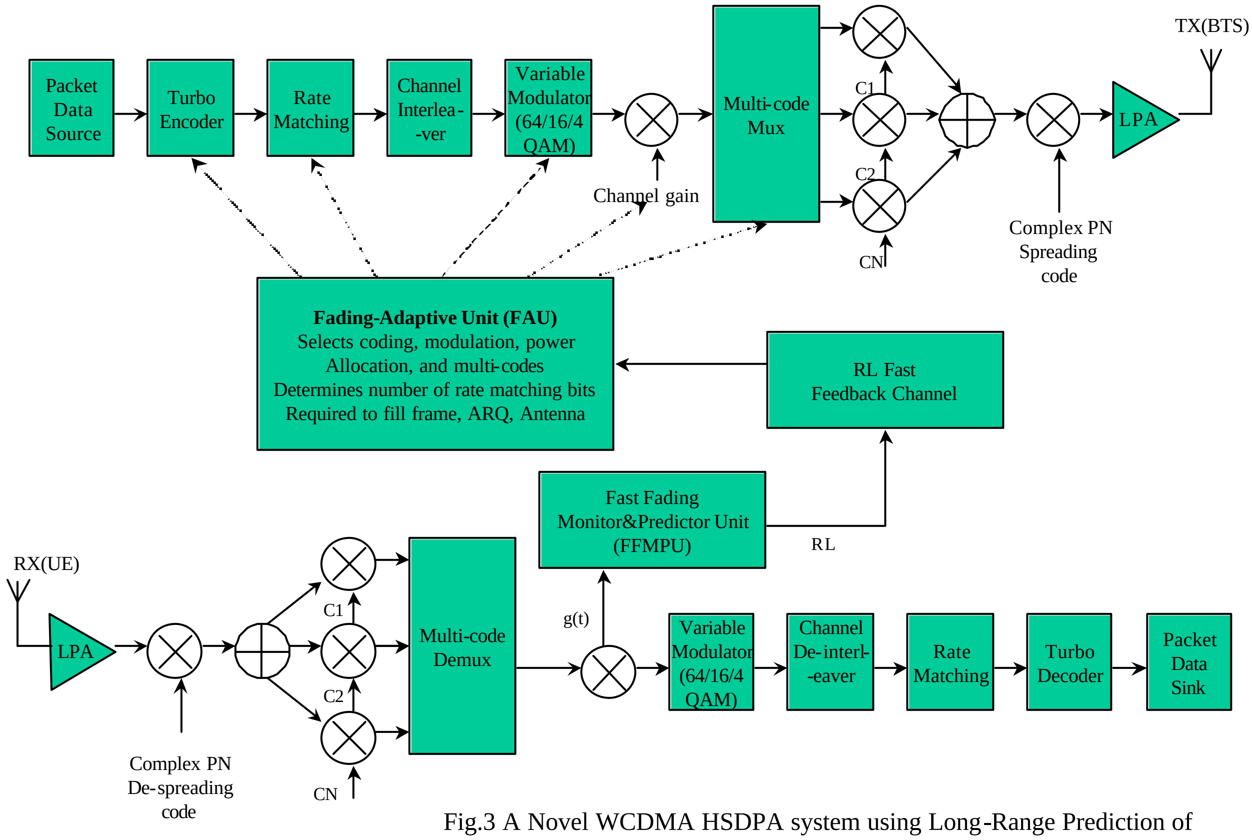

Fig.3 A Novel WCDMA HSDPA system using Long-Range Prediction of Fast Flat Fading