TSG-RAN Working Group 1 Meeting #17 **TSGR1#17(00) 1393**

Stocholm, Sweden
November 21-24, 2000

Agenda Item: AH24: High Speed Downlink Packet Access
Source: **Wiscom Technologies**
Title: Use of Long-Range Prediction for channel estimation and its application in HSDPA
Document for: Discussion

1 Introduction

The preliminary simulation results regarding the effect of channel estimation error on the link level performance of HSDPA showed [1,2,3] that the link 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. This issue has fundamental impact on limitation of HSDPA in terms of peak data rate and vehicle speed. This contribution is trying to propose an approach to improve the peak data rate and enable HSDPA [4] for higher vehicle speed.

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

$$P_{e16QAM} ? \frac{3}{8} ?1 ? \frac{1}{\sqrt{1 ? \frac{5}{2?_b}}} ? \quad (2)$$

$$P_{e64QAM} ? \frac{7}{24} ?1 ? \frac{1}{\sqrt{1 ? \frac{7}{?_b}}} ?$$

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.

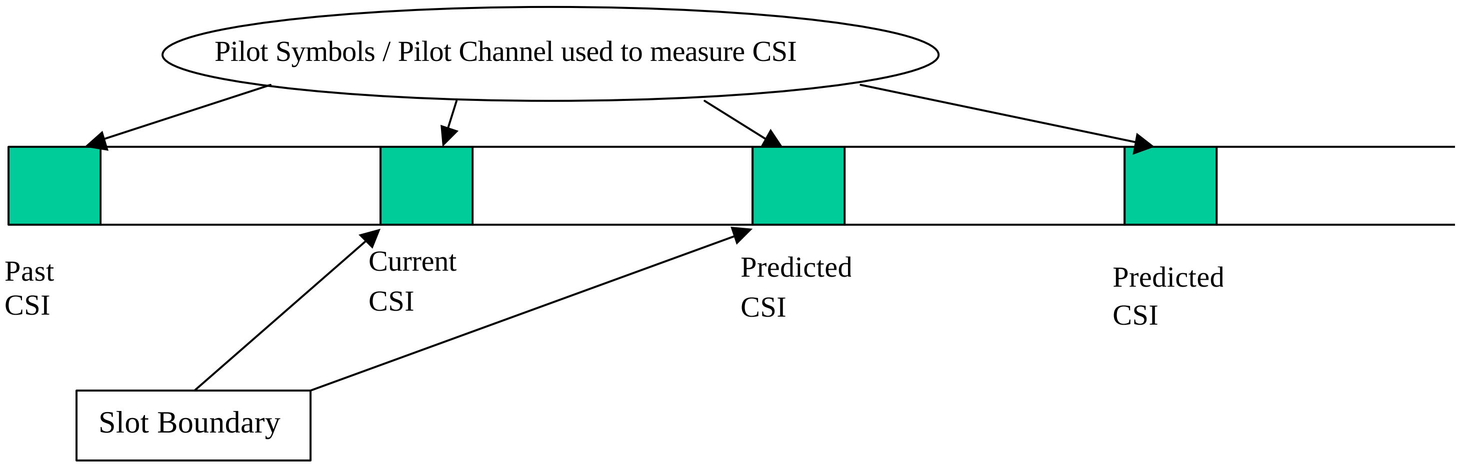

Fig. 1 The Channel State Information (CSI) is obtained using either time-multiplexed pilot symbols (transmitted in DPCCH) or code-multiplex pilot channel signals (transmitted in CPICH).

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, we propose to use this new tool to improve the performance of WCDMA, especially for HSDPA applications. 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. Our major contribution is to study how the proposed new system paradig m 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 seven 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] 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). The reason 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 amp litude 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 effic iency 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 that justify the use of 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 help the transmission efficiency using for a system using ARQ under flat Rayleigh fading channel conditions. Besides we know when f_d increases, transmission efficiency decreases because error-free length becomes short with increasing f_d. Obviously we know 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 cell 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 Conclusion

We claim

1. This system proposed in this invention can support higher peak data rate and throughput, compared with other non-adaptive systems.
2. This invention can be supported by the existing 3GPP WCDMA system structure, particularly the frame/slot structure.
3. This invention is valid for other similar systems where the frame structure supports the fast feedback from receiver to transmitter point.

More simulation results will be reported in the next TSG RAN WG1 meeting.

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] 3G TR V0.1.0 (2000-05), Physical Layer Aspects of UTRA High Speed Downlink Packet, 3GPP Release 2000, TSG-RAN Working Group1 meeting#16, TSGR1#16(00)1316, Pusan, Korea , 10th-13th Oct. 2000