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Maximum Likelihood Trellis Decoder for Golay Codes with Puncturing and Shortening for MIMO in HSPA+

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Abstract: ***HSDPA is based on shared channel transmission and its key features are shared channel and multi-code transmission, higher-order modulation, short Transmission Time Interval (TTI), fast link adaptation and scheduling along with fast hybrid Automatic Repeat request (ARQ). The HS-DPCCH channel is used in HSDPA by the UE to signal the Hybrid Automatic -Repeat-reQuest (HARQ) acknowledgements and the Channel Quality Information (CQI). The UE is using the CQI to indicate the instantaneous DL channel quality and that information is utilized in determining the UE that should be scheduled during the next TTI. This paper describes an effective working of the MIMO (Multiple Input Multiple Output) system, dependent on the accurate decoding of CQI & PCI values at the Base Transceiver station to provide flawless service to the MIMO service enabled UE. The possible values of CQI & PCI are between 0 to 1023 combinations which undergoes (20, 10) encryption at UE. The efficient decoding of the time crucial information is very much desired with least amount of complexity and highly efficient utilization of the resource available for improved downlink which provides higher data throughput with significantly reduced latency. Thus to reduce the cost per bit and enhances to mitigate the challenge to support for high-performance packet data applications for the current advent of smart phones available in the cellular communication eco-system.***

Keywords: ETSI, sMultimedi, PDC, Technology, UMTS,

1. Introduction

Mobile networks have evolved significantly during the last 3 decades. The mobile adventure started with the first generation (1G) of mobile networks. These networks were deployed during the 80s and characterized for being analogue, and their technology was optimized for voice. The second generation (2G) of mobile networks came next with overcoming many of the problems that 1G had. Digital technology was used in 2G networks. Three different systems were mainly standardized in the second generation: Global System for Mobile Communications (GSM), cdmaOne (IS-95), and Personal Digital Cellular (PDC). These technologies were standardized in Europe, US, and Japan respectively. The European standard, though, has been favored by many other countries and it has been deployed widely all around the world. According to [GSM_06], the number of GSM users in the world represents 77 % of the total mobile users.

GSM was first based on circuit switched technology, clearly as a legacy of the previous network technologies. Both voice and data services were offered using circuit switched technology; however, speeds for data services were fairly low. GSM was thought to provide voice services, not data services. GSM was eventually modified to work also with packet switched technology so data services could be offered at higher speeds. These networks were called 2.5G mobile networks. 2.5G networks were improved through High Speed Circuit Switched Data (HSCSD) service and General Packet Radio Service (GPRS). HSCSD was based on circuit switched technology while GPRS was based on packet switched technology.

Enhanced Data Rates for GSM Evolution (EDGE) followed the previous developments. Data speeds were improved significantly. EDGE is able, in theory, to achieve up to 384 Kbps which is far from the 9.6 Kbps offered by the first 2G networks.

The mobile networks evolution did not stop there. EDGE gave way to what is called third generation of mobile networks, 3G. 3G networks have been called differently in different places. Europe named it as Universal Mobile Telecommunication System (UMTS), while in Japan and US, 3G networks were named as International Mobile Telephony 2000 (IMT-2000). UMTS is the name given by the European Telecommunication Institute (ETSI); however, the International Telecommunications Union (ITU) preferred IMT-2000.

3G networks are designed to provide voice and data service in an efficient way. Hence, bit rates have been further improved compared to the other network generations. 3G is able to provide, in theory, up to 2 Mbps as specified in 3GPP Release '99, and up to 10 Mbps as specified in 3GPP Release 5. Not only 3G provides data and voice services, 3G is built over a new technology which is focused in providing better end-user experience through new services and applications, widely known as multimedia services.

Unlike 1G and 2G networks, which provided none or limited compatibility with other networks of the same generation, 3G networks are supposed to provide compatibility and interoperability worldwide with any other 3G network. Despite the promises of 3G to provide multimedia services at high speed rates, it has turned out that 3G networks could not offer what was expected. Few enhancements have been

done along the way resulting in a new mobile generation, 3.5G. These improvements are the result of both the necessity of coping with the new emerging competing technologies, such as CDMA-2000 or WiMAX, and the necessity of providing high bit rates. 3GPP standardized a new technology called High Speed Downlink Packet Access (HSDPA). HSDPA is able to increase the bit rate up to 10 Mbps. Chapter 3 explains in detail HSDPA technology and features.
Although HSDPA achieves high bit rates in the downlink, some applications, such as real time applications, need similar bandwidth in both downlink and uplink. For this reason, the 3GPP is standardizing the natural technology for the uplink, High Speed Uplink Packet Access (HSUPA) presents a brief overview of the technological aspects of HSUPA. Fourth Generation (4G) of mobile networks is now in use. 4G goes along with two statements: communications convergence, and "All-IP". 4G networks are supposed to be fully interoperable and compatible to any mobile technology in a seamless way for the users. 4G networks will provide extremely high bit rates, and a vast number of services among other benefits.

2. Motivation

HSDPA is still a young technology and it is not fully implemented in real networks. Hence, it is difficult to assess how this technology will behave and which its real performance is. Nonetheless, operators as well as manufacturers are investing in this technology. This is clearly a risk which manufacturers and operators need to mitigate as much as possible in order to succeed. There are many research documents about HSDPA. Most present how HSDPA performs over other technologies. However, they fail to take into consideration how HSDPA would perform in real situations, when there are certain types of traffic and a certain amount of users. Most of them do not study the network and end-user performance. This paper will deal with these issues.

3. Problem Definition

With the channelization codes chosen for HS-DPCCH are shown in Table 1. By closer observation one can see that the channelization code chosen for HS-DPCCH when one UL-DPDCH is active is exactly the same as for the UL-DPDCH. This means that we would not need additional fingers to receive the HS-DPCCH channel. The only difference is that HS-DPCCH is transmitted in the Q-branch and UL-DPDCH in the I-branch. That is, just sum the UL-DPDCH symbols from minimum SF to 256 and then choose the Q-branch instead of the I-branch. Also because the dedicated data is transmitted in the I-branch it is very important that the channel is need to be estimated correctly because otherwise there will be crosstalk between the branches. The crosstalk between the channels will make it difficult to estimate.

Table 1: Channelization code of HS-DPCCH

Nmax-dpdch (max number of UL-DPDCH over all the TFCs in the TFCS)	Channelization code Cch
1	Cch,256,64 == SF/4
2,4,6	Cch,256,1
3,5	Cch,256,32

Thus an efficient decoding of the time crucial information is very much desired with least amount of complexity and highly efficient utilization of the resource available was very much needed

4. Objectives

This paper will explain HSDPA and identify the challenges it has to face. It will also provide the answers that the previous section arose. A simulator will be built in order to find some answers. This simulator aims to discover the maximum number of HSDPA users in one cell in different situations, such as for example when all users within that cell are using MIMO services. Different parameters will be modified to see the effect of them in the end-user performance. These parameters are the user/session inter-arrival time and the mean cell throughput. Different performance parameters will be collected in order to learn how the network and the users are affected by the types of traffic and number of simultaneous users. These key values will provide the current performance indicators for the simulated environment. Current performance indicators will be compared to some recommended (standardized) Key Performance Indicators (KPI) which, in turn, can be mapped into certain QoS and Quality of Experience (QoE) values. KPIs, QoS and QoE values will limit the maximum number of users that the network is able to give service.

5. Results

A. Simulation Assumptions:

Table 2 summarizes the parameters used in the conformance test simulations. Some parameters are different in the other simulations but they are explicitly stated.

Table 2: Simulation Parameter Summary

Parameter	Assumptions
Carrier Frequency	2 GHz
Chip rate	3.84 Mcps
Receiver antenna diversity	2 branch diversity with correlation *r = 0.*
Number of samples per chip	2 (interpolated inside the receiver to 8)
Number of RAKE fingers	8
Channel estimation	Cannot be disclosed
Delay estimation	Cannot be disclosed
DPCCH/ DPDCH power offset	-2.69 [dB]
Closed loop power control	OFF
HS-DPCCH repetition	1
HS-DPCCH power offset to DPCCH	0 dB
HS-DPCCH timing offset to DPCCH	0 symbol

Service	12.2kbps+DCCH
Channelization code for UL-DPCCH	Ch(256,0) (3GPP TS 25.213)
Channelization code for UL-DPDCH	Ch(64,16) = (64/4) (3GPP TS 25.213)
Channelization code for HS-DPCCH	Ch(256,64) (3GPP TS 25.213)
Propagation conditions	AWGN, Case1, Case2, Case3 (3GPP TS 25.141)
Simulation time in sub-frames	>30000

B. Simulation Results:

The simulation results include figures for CQI BLER. Also BLER curves of the DPCH service are included for obtaining the operating point. The simulations are divided into three parts. The Part 1 includes some simulations results about the crosstalk between the channels and motivates why an extra carrier frequency error rotation is needed. Part 2 includes simulations results for the conformance test cases, which motivates why an extra carrier frequency error rotation is needed.

Part 1: Crosstalk between the channels

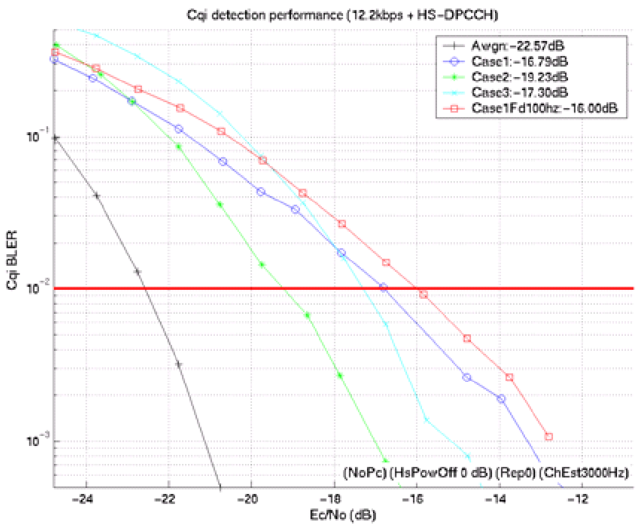

Figure 1: CQI detection performance (power offset 0dB)

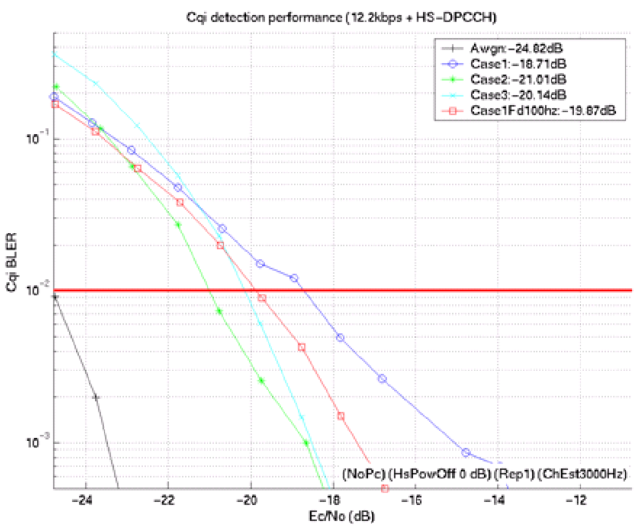

Figure 2: CQI detection performance (power offset 0dB)

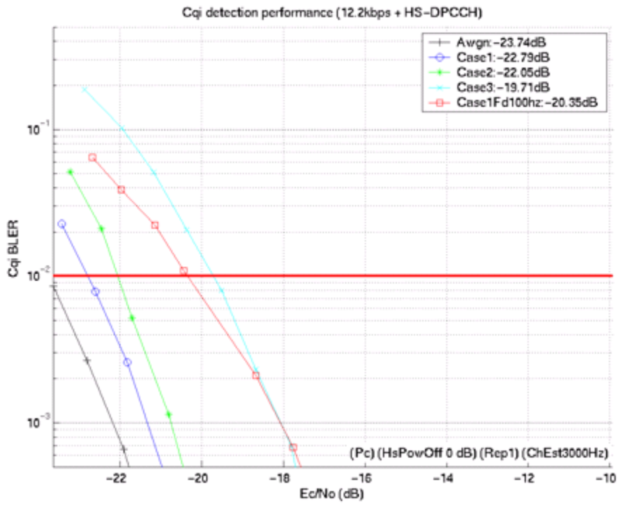

Figure 4: CQI detection performance (power offset 0dB, one repetition)

Simulation results with power control in conformance test conditions. As was expected the power control is taking the results for the low mobility cases close to the AWGN case. HSDPA is able to achieve a theoretical bit rate of up to 14.4 Mbps. However, due to technological limitations, the maximum bit rate is likely to be closer to 10 Mbps. This fact implies that HSDPA increases the spectral efficiency to the level of being close to the Shannon limit. Moreover, due to the fact that scheduling, retransmissions, modulation and coding decisions are taken nearer of the air interface, HSDPA will reduce significantly system delays.

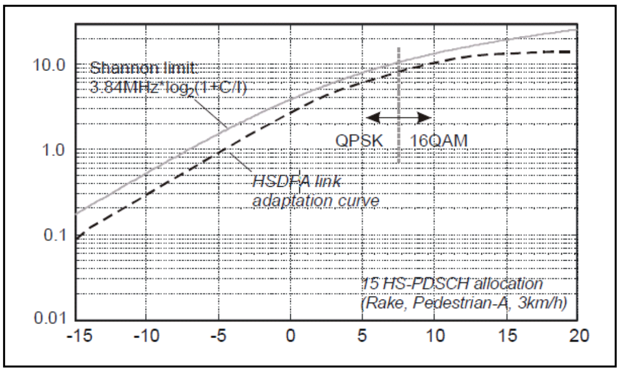

Figure 4: HSPA data rate vs Shannon limit

Fig 4 shows the plot of HSPA data rate vs Shannon limit. As the result, HSDPA shows to be the best solution to carry non-real time traffic, for instance interactive class or background class. HSDPA will also aim to carry streaming traffic in further releases; however, there may be certain limitations depending on the type of streaming traffic which is sent. Thus with the implementation of the CQI coding with the Golay codes the results confirmed in the Matlab that the Vehicular-A radio conditions can be mitigated as a normal AWGN case taking the UE to the low mobility cases

6. Conclusion

Several conclusions can be achieved after studying the results. The first finding is related to the amount of users versus the mean cell throughput. The number of UEs increases linearly when the mean cell throughput increases.

The optimum number of UEs (from the operator point of view) was found for different typical mean cell throughputs. All these intermediate conclusions lead us to the first chunk of final conclusions.

- HSDPA seems to perform very well on decoding algorithm with Golay decoding algorithm implementation.
- Hardware and software seems to be a bigger constraint than the air interface itself if the air interface can offer the average bit rates assumed in the study. Real implementations will have power limit constrains and admission control algorithms; timers and counters which can affect the network and user performance; and other hardware limitations such as the number of HSDPA users that hardware can support.
- Until the optimum number of UEs, the network and user performance does not deteriorate significantly. Once the optimum number of UEs is exceeded, the throughput is undesirable and there in chips in the implications of our algorithm.
- Thus, Go-lay decoding algorithms will play an important role in the overall HSDPA network performance. These algorithms will cause a need to keep the amount of users below the maximum level.

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