

無線網路多媒體系統 Wireless Multimedia System

Lecture 6: CDMA & 3G Trend
吳曉光博士



Agenda

- ◆ Spread Spectrum (Multipath, interferences from other cells)
- ◆ W-CDMA
- ◆ Evolutions of PCS
- ◆ ALL IP Challenges
 - Mobile IP/Cellular IP
 - QoS Provisions: Integrated Service / DiffServ
- ◆ Next Week (Mobile IP)



Reading

- ◆ [Kohn95]Ryuji Kohno, Reuven Meidan, and Laurence B. Milstein Spread Spectrum Access Methods for Wireless Communications, IEEE Communication Magazine, 1995
- ◆ [Dahlman98]Erick Dahlman, Bjorn Gudmundson, Mat Nilsson and Johan Skold, UMTS/IMT-2000 Based on Wideband CDMA, IEEE Communication Magazine 1998
- ◆ [Ojanpera98] T. Ojanpera, R. Prasad, "An Overview of Third-Generation Wireless Personal Communications: An European Perspective, IEEE Personal Communication Magazine 1998



Code Division, Spread Spectrum



What is Going to Happen in CDMA?



CDMA Era

Pioneer Era	
1949	John Pierce: time hopping spread spectrum
1949	Claude Shannon and Robert Pierce: basic ideas of CDMA
1950	De Rosa-Rogoff: direct sequence spread spectrum
1956	Price and Green: antimultipath "RAKE" patent
1961	Magnuski: near-far problem
1970s	Several developments for military field and navigation systems
Narrowband CDMA Era	
1978	Cooper and Nettleton: cellular application of spread spectrum
1980s	Investigation of narrowband CDMA techniques for cellular applications
1986	Formulation of optimum multiuser detection by Verdu
1993	IS-95 standard
Wideband CDMA Era	
1995	Europe :FRAMES FMA2
	Japan :Core-A
	USA :cdma2000
	Korea :TTA I TTA II
2000s	Commercialization of wideband CDMA systems



Digital to Analog Modulation

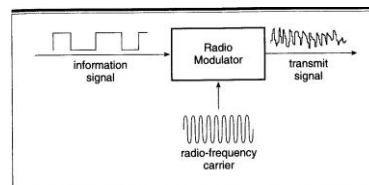


Figure 6.2 Single-stage digital modulation (TDMA and FDMA).



Digital-Digital-Analog Modulation

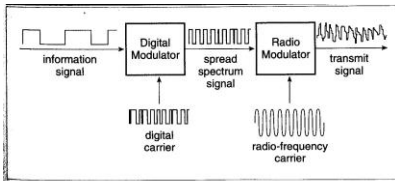


Figure 6.3 Two stages of modulation in a spread spectrum system.



Digital-Digital-Analog Modulation

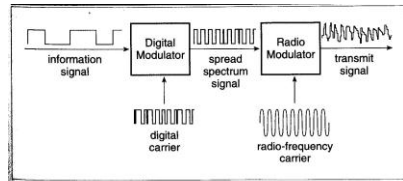


Figure 6.3 Two stages of modulation in a spread spectrum system.



Digital Correlator

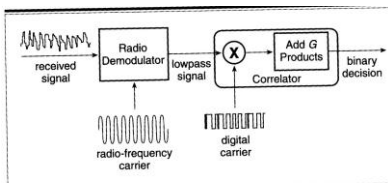


Figure 6.4 Two stages of demodulation in a spread spectrum receiver.



DS-CDMA



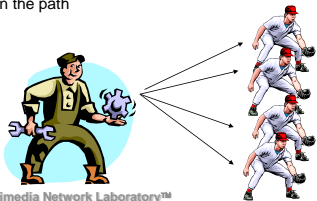
- Processing Gain:
- SF=2 cases:
 - $(1, 1) \otimes (1, 1) = 1+1=2$ (Processing Gain)
 - $(1, 1) \otimes (1, -1) = 1-1=0$ (orthogonal)
- SF=4 cases:
 - $(1, 1, 1, 1) \otimes (1, 1, 1, 1) = 1 + 1 + 1 + 1 = 4$ (Processing Gain)
 - $(1, 1, 1, 1) \otimes (1, 1, -1, -1) = 1 + 1 - 1 - 1 = 0$ (Orthogonal)
- $SIR = Pr * \text{Processing Gain} / \text{Interference}$
- $= Pr * (\text{Total_Radio_Frequencyband} / \text{Bitrate}) / \text{Interference}$



Multiple correlators



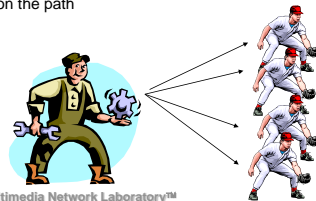
- Multiple correlators in each receiver
- At any instant of time, the signal carriers in the different correlators are synchronize to signal paths with different propagation times
- A search circuit examines the arriving signal in order to detect the appearance of a new path, then assign a correlator to synchronize the signal on the path



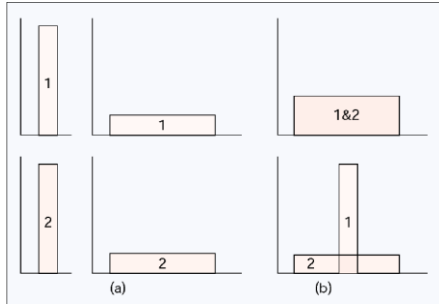
Multiple correlators



- Multiple correlators in each receiver
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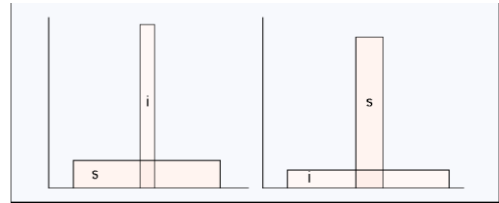
Spread Spectrum Multiple Access



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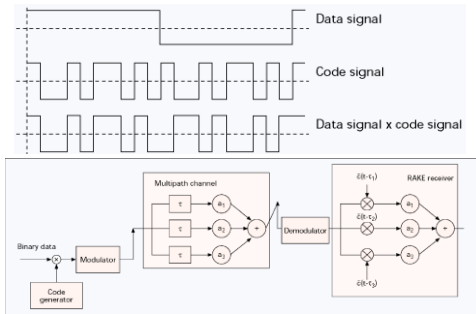
Interference Rejection



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Spread Spectrum Signal



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CDMA Concept

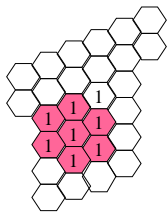


- ◆ Multiple Access Capability
- ◆ Protection Against Multipath Interference
- ◆ Interference Rejection
- ◆ Anti-Jamming Capability – Especially Narrow Band Jamming
- ◆ Low Probability Interception

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Direct Sequence Cellular



Idealized grid of Hexagonal cells

- ◆ DS spread spectrum signals are generated by linear modulation with wideband PN sequences which are assigned to individual users
- ◆ Universal Frequency Reuse: One-cell frequency reuse pattern
- ◆ Introduction of a new cell will be less restricted than in the case of either FDMA or TDMA
- ◆ (FDD) Frequency Division Duplex Operation: One frequency band is used for the base-to-mobile (forward or down link), one frequency band is used for the mobile-to-base link (the reverse link or uplink)

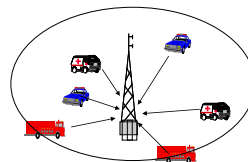
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Power Control (Reverse Link)



- ◆ Reverse Link: asynchronous, asynchronous CDMA system is vulnerable to the "near-far" problem
- ◆ Power Control: minimize consumption of the transmitted power, fast enough to compensate for Rayleigh fading
- ◆ Capacity is bounded by number of users (MAI Multiple Access interferences)



Everybody has a Code (PN), asynchronous



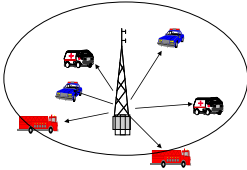
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Power Control (Forward Link)



- Forward Link: the users can be orthogonalized, (however, the orthogonalization is not preserved between different paths of the multipath propagation, nor is it preserved between the forward links of different cells)
- Power Control: Since the cell's signals can be received at the mobile with equal power, the forward link does not suffer from near-far problem
- Cell boundary



Everybody has a Code (PN) synchronous



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Cellular Capacity



- Capacity of the reverse link (typically asynchronous link)

$$\left(\frac{E_b}{\eta_0}\right)_{\text{eff}} = \frac{1}{\frac{\eta_0}{E_b} + \frac{2}{3G}(M-1)(1+K)\alpha}$$



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Radio Resource Management



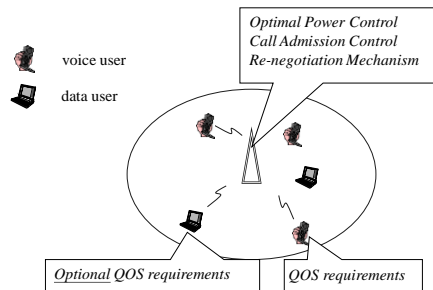
- Power as the common resource makes W-CDMA very flexible
 - Link improvement, less power, more capacity
- Orthogonal variable spreading factor (OVSF) for variable bit rate



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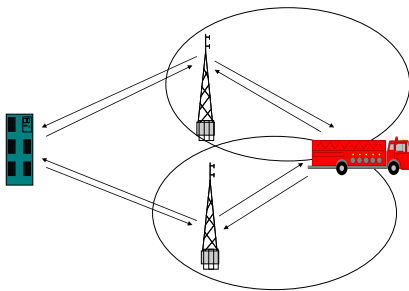
Call Admission Control



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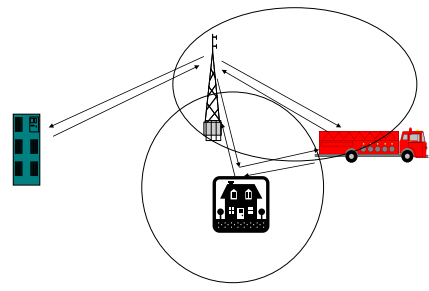
Soft Handovers (Macro Diversity)



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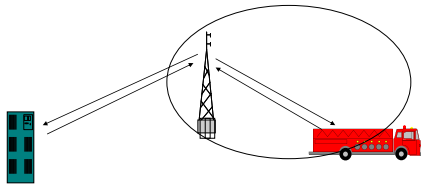
Softer Handovers (Space Diversity)



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Power Control (Open & Close Loop)

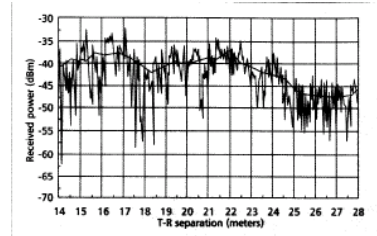


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Close-Loop Power Control

- ◆ Compensates a fading channel (1500 times per second)



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UMTS/IMT-2000 Based on Wideband CDMA



What is going to happen for WCDMA

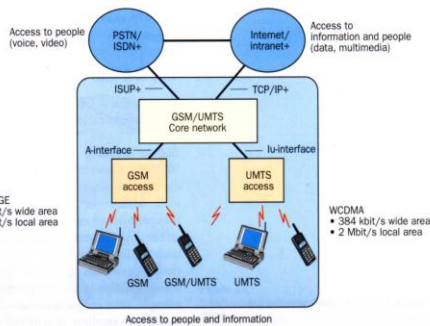
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Application Support in UMTS

- ◆ UMTS (Universal Mobile Telecommunication System)
- ◆ UTRA (UMTS Terrestrial Radio Access)
- ◆ Support:
 - 384 kb/s for wide-area coverage
 - 2 Mb/s for local coverage
- ◆ Multimedia Applications Requirements
 - Packet-oriented
 - Variable bit rate
 - Network resources can be available on a shared basis
 - E_b/N_0

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RS Spectrum Allocation

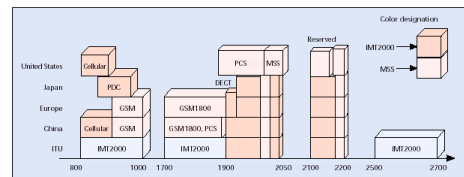
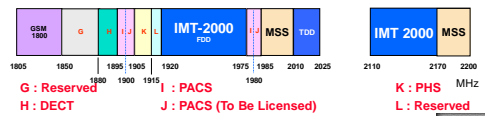


Figure 2. RF spectrum allocation in major regions.



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Wireless Mobile Interface

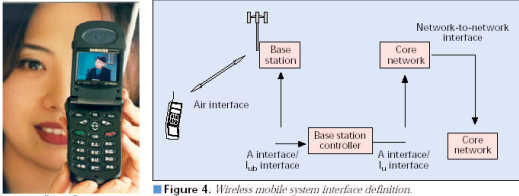
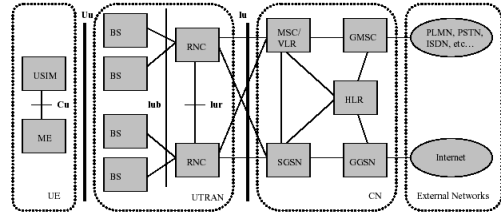


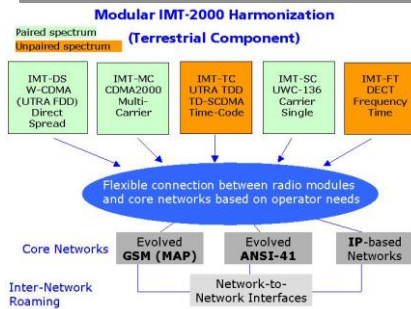
Figure 4. Wireless mobile system interface definition.



Elements of UMTS Architecture



第三代行動電話之技術標準



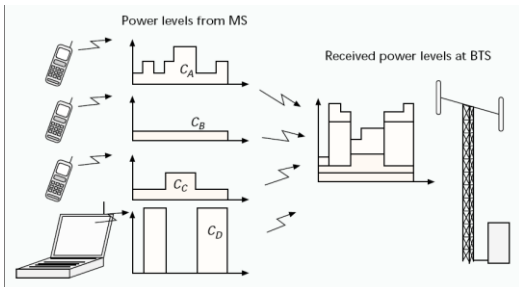
Key W_CDMA Features



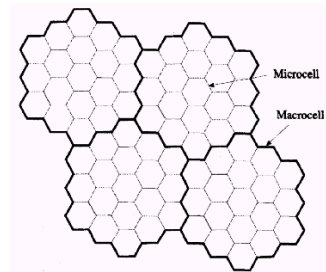
- Performance Improvements
 - Capacity Improvements (3 dB, 384 kb/s, 1.9 Mb/s, 130 users)
 - Coverage and Link Budget Improvements (reuse GSM cell, 144 kb/s)
- Service Flexibility
 - Support of a wide range of services with maximum rate of 2 Mb/s, the possibility for multiple parallel services on one connection
 - A fast and efficient packet-access scheme
- Operator Flexibility
 - Support of asynchronous inter-base-station operation
 - Efficient support of different deployment scenarios, HCS, hot-spot
 - Support of evolutionary technologies such as adaptive antenna arrays and multi-user detection
 - A TDD mode designed for efficient operation in uncoordinated environment



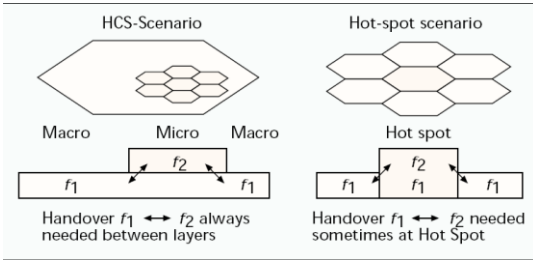
Multiplexing variable bit rate users



An example of two-tier cellular system



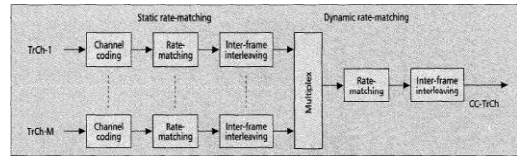
Handoff



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Transport of the channel



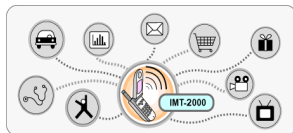
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About 3G



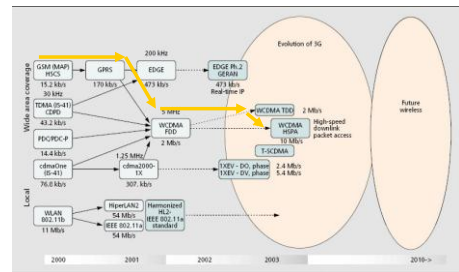
- Organization :
 - 3GPP (3rd Generation Partnership Project)
 - 3GPP2 is the standardization group for IS-95 (CDMA)
- IMT-2000 (International Mobile Telephony 2000)
 - global standard proposed by the ITU
- IMT-2000 3G standards :
 - TD-SCDMA
 - CDMA2000
 - W-CDMA



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Development : 2G to 3G



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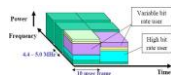


WCDMA



Wideband CDMA

- DS-SS-CDMA
- Use spreading factors 4 - 512 to spread the base band data over ~5MHz band.



Multiple access method	DS-SS-CDMA (Direct-Sequence - CDMA)
Duplex method	FDD / TDD
Chip rate	3.84 Mcps
Frame length	10 msec
Base station frequency	Asynchronous operation
Service multiplexing	Multiple services with different quality of service requirements multiplexed on one connection
Multi-rate concept	Variable spreading factor and multi-code

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UMTS/WCDMA Features



- Speed :
 - UMTS 384Kbps up to 2Mbps
- Bands :
 - Asia & Europe 2100MHz North America 800 & 1900MHz
- Applications :
 - Email, internet, fax, music, image, video...etc
- Global Access :
 - Users can move between GSM, GPRS and UMTS coverage areas without dropping connections or losing access to their network.



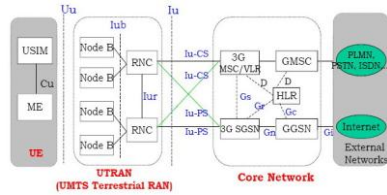
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UMTS Architecture



- Core Network : Connection with External Networks
- UTRAN : Functions about Radio
- UE : communication between air interface and users.



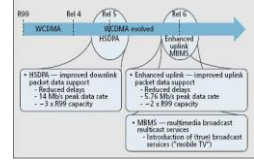
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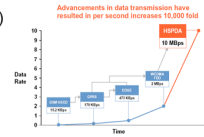
First Step of HSPA - HSDPA



- WCDMA R5
 - Proposed by 3GPP on 2001
 - HSDPA Technique



- HSDPA (High Speed Downlink Packet Access)
 - Data rate 3Mbps up to 14Mbps
 - 3 times Capacity
 - Backward compatible with WCDMA



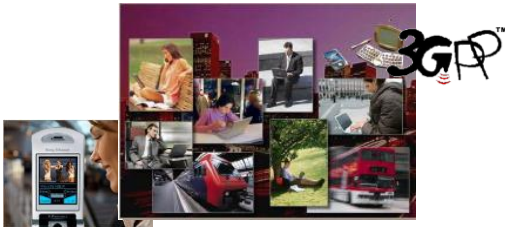
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Enhanced WCDMA - 3.5G HSDPA



- Defined in 3GPP Release 5.
- Higher data rate : 2Mbps~14Mbps



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HSDPA Characteristic



- New Transport Channel
 - HS-DSCH
- Short TTI
 - 2ms
- AMC
 - Modulation :
 - QPSK(2bits/symbol)
 - 16QAM(4bits/symbol)
 - Channelized code 1~15
- HARQ
 - SAW HARQ (simplest and little overhead)
- Fast Scheduling
 - Do packet Scheduling and retransmission in Node B



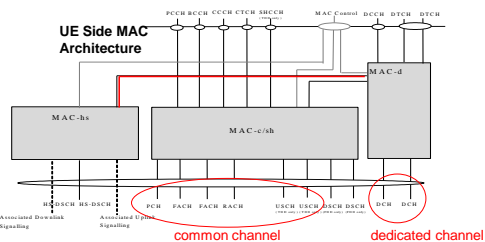
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MAC Architecture



- UTRAN Side MAC entity is similar to the UE side except that there will be one MAC-d for each UE.



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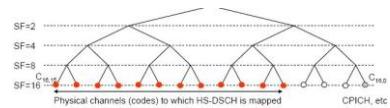
SF and Modulation



- QPSK can show 2 bits per symbol, and 16QAM can show 4 bits per symbol.



- Channelization code at a fixed SF = 16.



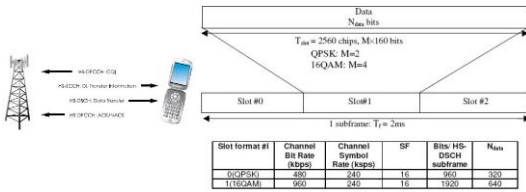
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HS-PDSCH



- HS-PDSCH carries the data traffic in terms of MAC-hs PDU.
- Fixed SF=16; up to 15 parallel channels
- 14Mbps = 960 x 15 ~ = 14400 kbps



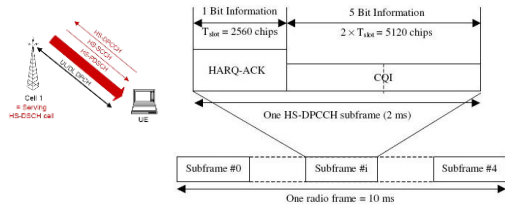
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HS-DPCCH



- HS-DPCCH feedbacks ACK/NACK and channel quality information (CQI).
- Fixed SF=256.



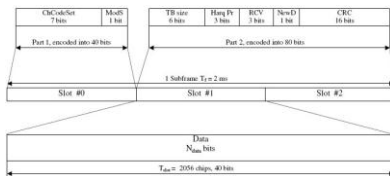
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HS-SCCH



- Fixed SF=128 : UE can monitor up to 4 HS-SCCH simultaneously.
- HS-SCCH signals the configuration to be used next.



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DCH, DSCH and HS-DSCH



Feature	DCH	DSCH	HS-DSCH
Variable SF	Yes (4 – 512)	Yes (4 – 256)	No (16)
Fast power control	Yes	Yes	No
Modulation	QPSK	QPSK	Adaptive using QPSK (16QAM)
HARQ	No	No	Yes
TTI	10 to 80 ms	10 or 20 ms	2 ms
Multi-Code operation	Yes (up to 6)	Yes (up to 6)	Yes (extended to 15)
Mac Processing	RNC	RNC	Node B

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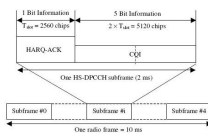


CQI (Channel Quality Indicator)



- Estimate the channel quality from CPICH and feedback CQI via HS-DPCCH cyclically. (In Spec25.331 k = 0,2,4,8,10,20,40,80,160)
- Delay and error of bits affect the accuracy of estimation.

$$CQI = \begin{cases} 0 & SNR \leq -16 \\ \frac{SNR + 16.62}{1.02} & -16 < SNR < 14 \\ 30 & 14 \leq SNR \end{cases}$$



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UE Category



- Classify the UE category base on the capability of UE.

Category	Codes	Inter-TTI	TB Size	Total # of Soft Bits	Modulation	Data Rate
1	5	3	7300	19200	QPSK/16QAM	1.2 Mbps
2	5	3	7300	28800	QPSK/16QAM	1.2 Mbps
3	5	2	7300	28800	QPSK/16QAM	1.8 Mbps
4	5	2	7300	38400	QPSK/16QAM	1.8 Mbps
5	5	1	7300	57600	QPSK/16QAM	3.6 Mbps
6	5	1	7300	67200	QPSK/16QAM	3.6 Mbps
7	10	1	14600	115200	QPSK/16QAM	7.2 Mbps
8	10	1	14600	134400	QPSK/16QAM	7.2 Mbps
9	15	1	29432	172800	QPSK/16QAM	10.2 Mbps
10	15	1	29776	172800	QPSK/16QAM	14.4 Mbps
11	5	2	3650	14400	QPSK only	0.9 Mbps
12	5	1	3650	14400	QPSK only	1.8 Mbps

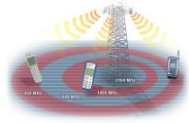
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UE Category 1-6 CQI table



Cell value	Transport Block Size	Number of RBs PDSCH	Modulation	Reference power adjustment A	M _{CS}	Q _m
0	N/A					
1	137	1	QPSK	0	16000	0
2	173	1	QPSK	0		
3	233	1	QPSK	0		
4	317	1	QPSK	0		
5	377	1	QPSK	0		
6	461	1	QPSK	0		
7	650	2	QPSK	0		
8	792	2	QPSK	0		
9	931	2	QPSK	0		
10	1262	3	QPSK	0		
11	1463	3	QPSK	0		
12	1742	3	QPSK	0		

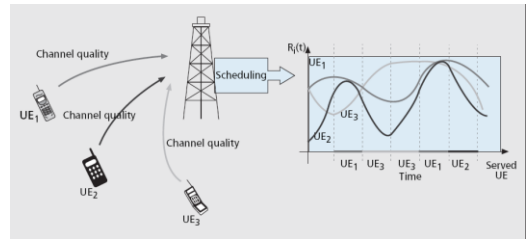


20	5887	5	16-QAM	0		
21	6554	5	16-QAM	0		
22	7168	5	16-QAM	0		
23	7168	5	16-QAM	-1		
24	7168	5	16-QAM	-2		
25	7168	5	16-QAM	-3		
26	7168	5	16-QAM	-4		
27	7168	5	16-QAM	-5		
28	7168	5	16-QAM	-6		
29	7168	5	16-QAM	-7		
30	7168	5	16-QAM	-8		

Wireless



Scheduling based on User Channel Quality (CQI), IEEE Network 2007



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Round Robin vs. Proportional Fair Scheduler

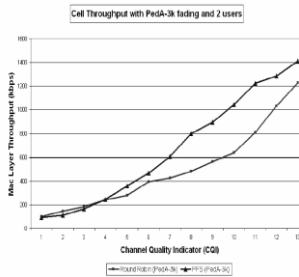
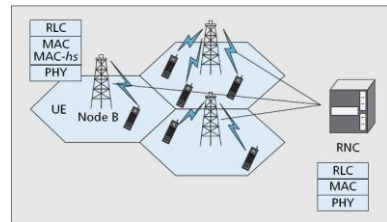


Fig. 1. Performance comparison between Proportional Fair Scheduler and Round Robin in lab, in a low mobility scenario (Ped A)

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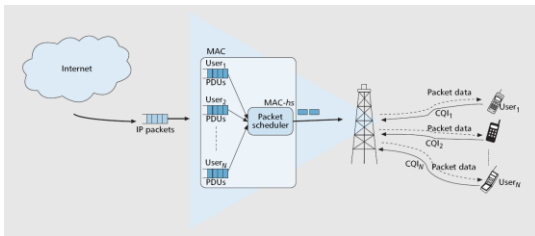
Scheduling from RNC to Basestation (Node B)



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Packet Scheduler Model in HSDPA



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Performance of HSDPA, IEEE VTJ 2007

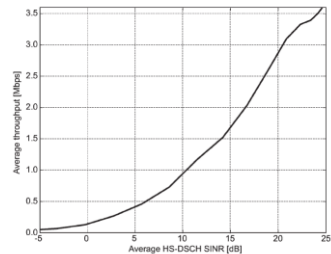


Fig. 5. Single-user HSDPA throughput as a function of the average HS-DSCH SINR.

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DCH vs HSPDA

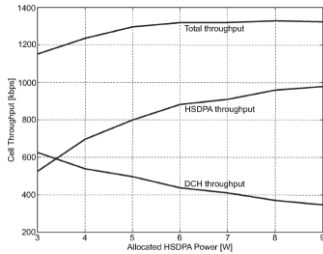
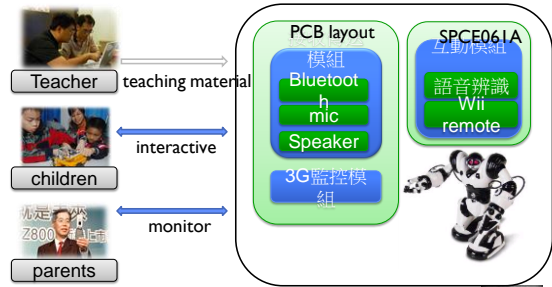


Fig. 7. Average cell throughput versus the allocated HSDPA power. PF scheduling is assumed, with five HS-PCDSCH codes and six HSDPA users per cell.

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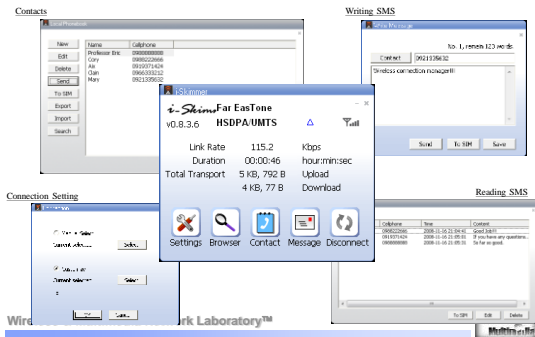
System Architecture



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Interface and Use Scenario



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Interface and Use Scenario



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