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

- [Kohno95]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 ┐ WCDMA
	Japan :Core-A ┘
	USA :cdma2000
	Korea :TTA I TTA II
2000s	Commercialization of wideband CDMA systems

Digital to Analog Modulation

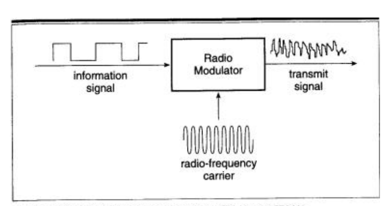

Figure 6.2 Single-stage digital modulation (TDMA and FDMA).

Digital-Digital-Analog Modulation

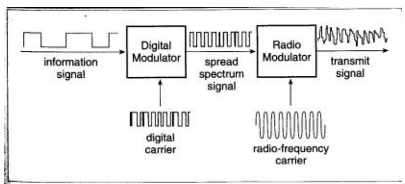

Figure 6.3 Two stages of modulation in a spread spectrum system.

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Digital-Digital-Analog Modulation

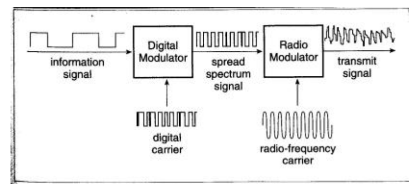

Figure 6.3 Two stages of modulation in a spread spectrum system.

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Digital Correlator

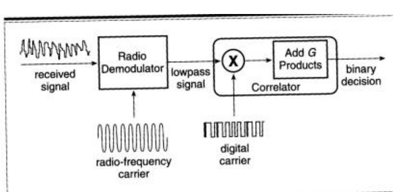

Figure 6.4 Two stages of demodulation in a spread spectrum receiver.

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DS-CDMA

- Processing Gain:
- SF=2 cases:
- (1, 1) ⊗ (1, 1) = 1+1=2 (Processing Gain)
- (1, 1) ⊗ (1,-1) = 1-1=0 (orthogonal)
- SF=4 cases:
- (1, 1, 1, 1) ⊗ (1, 1, 1, 1) = 1 + 1 + 1 + 1 = 4 (Processing Gain)
- (1, 1, 1, 1) ⊗ (1, 1,-1,-1) = 1+ 1 – 1 -1 =0 (Orthogonal)
- SIR = Pr * Processing Gain / Interference
- = Pr * (Total_Radio_Frequencyband / Bitrate) / Interference

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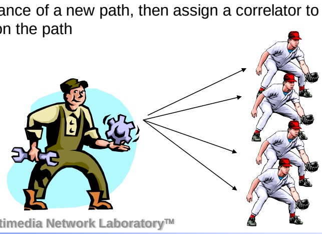
Multiple correlators

- 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



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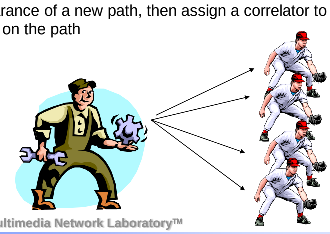

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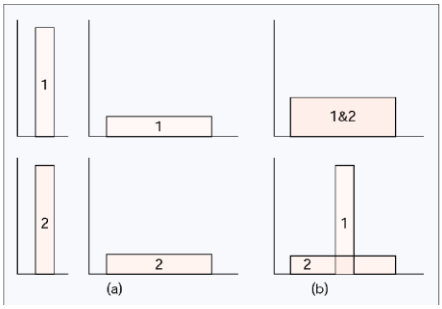
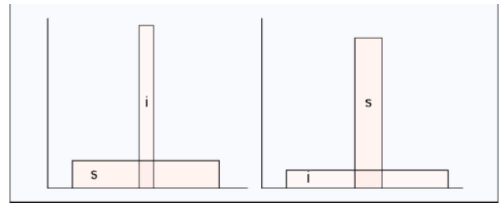
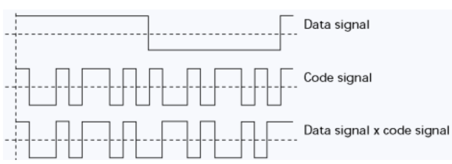
Spread Spectrum Multiple Access

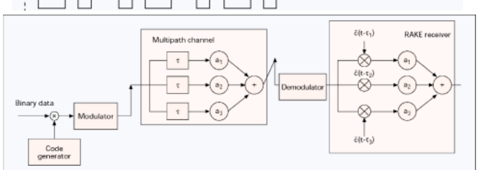


Interference Rejection



Spread Spectrum Signal

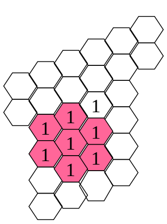




CDMA Concept

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

Direct Sequence Cellular

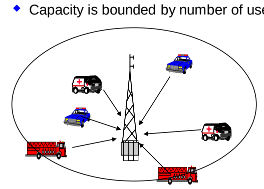


Idealized grid of
Hexagonal cells

- 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)

Power Control (Reverse Link)

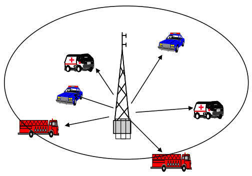
- Reverse Link: asynchronous, asynchronous CDMA system is vulnerable to the “near-far” problem
- Power Control: minimize consumption of the transmitted power, fast enough to compensate for Rayleigh fading
- Capacity is bounded by number of users (MAI Multiple Access interferences)



Everybody has a Code (PN), asynchronous

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

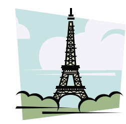


Everybody has a Code (PN) synchronous

Cellular Capacity

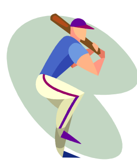
- Capacity of the reverse link (typically asynchronous link)

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

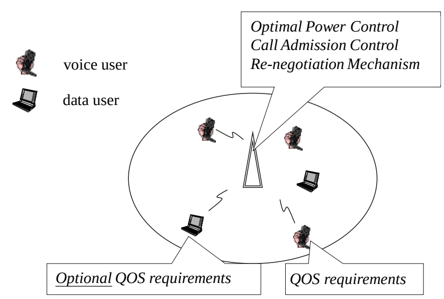


Radio Resource Management

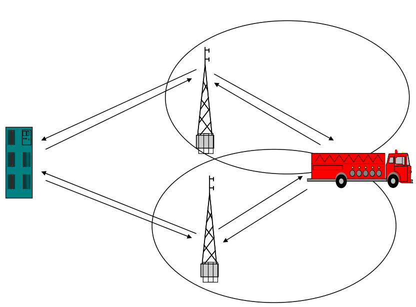
- Power as the common resource makes W-CDMA very flexible
  - Link improvement, less power, more capacity
- Orthogonal variable spreading factor (OVSF) for variable bit rate



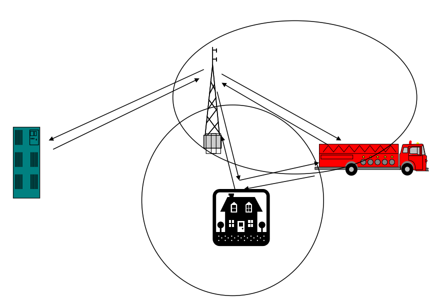
Call Admission Control



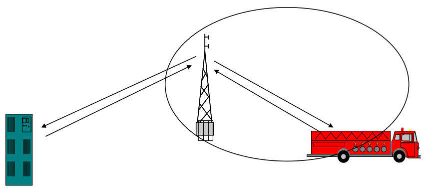
Soft Handovers (Macro Diversity)



Softer Handovers (Space Diversity)

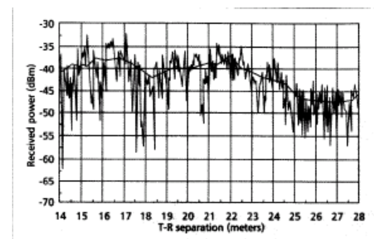


Power Control (Open & Close Loop)



Close-Loop Power Control

- Compensates a fading channe(1500 times per second)

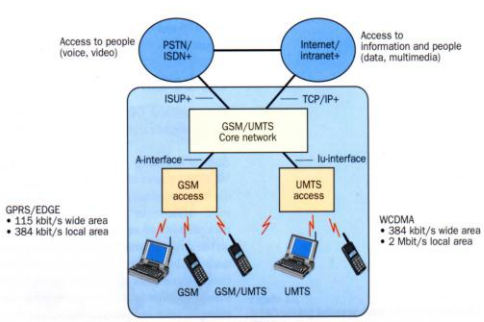


UMTS/IMT-2000 Based on Wideband CDMA

What is going to happen for WCDMA

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



RS Spectrum Allocation

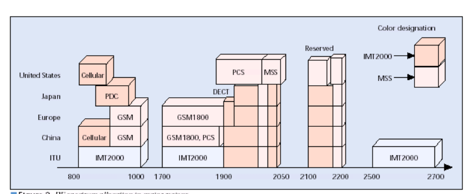
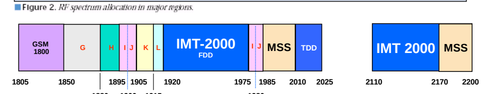


Figure 2. *RF spectrum allocation in major regions.*



G : Reserved
H : DECT
I : PACS
J : PACS (To Be Licensed)
K : PHS
L : Reserved

Wireless Mobile Interface

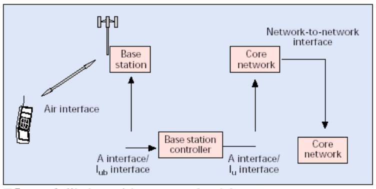
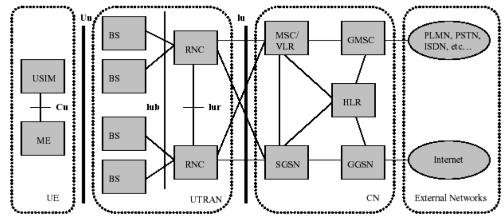
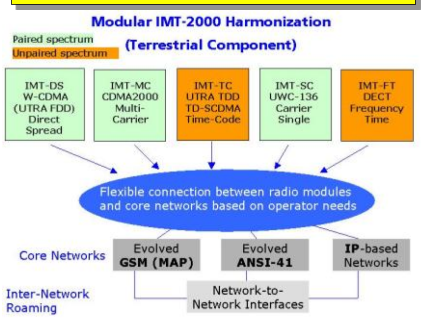


Figure 4. *Wireless mobile system interface definition.*

Elements of UMTS Architecture



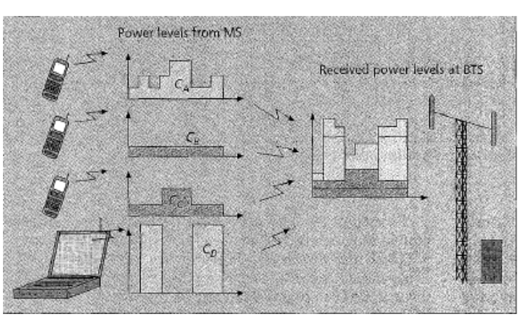
第三代行動電話之技術標準



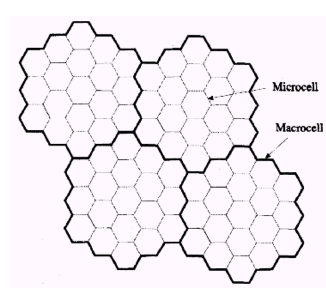
Key W_CDMA Features

- 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-sport
  - Support of evolutionary technologies such as adaptive antenna arrays and multi-user detection
  - A TDD mode designed for efficient operation in uncoordinated environment

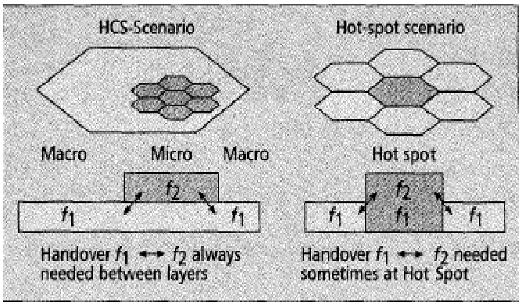
Multiplexing variable bit rate users



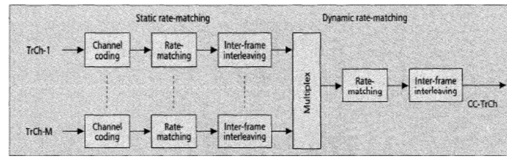
An example of two-tier cellular system



Handoff

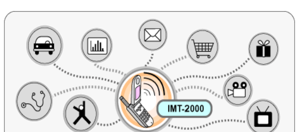


Transport of the channel

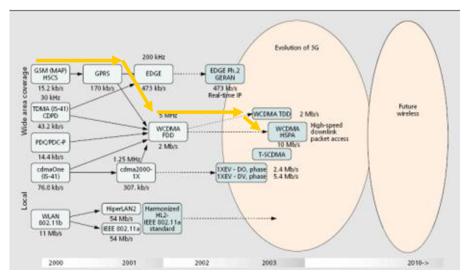


About 3G

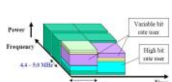
- Organization：
  - 3GPP (3rd Generation Partnership Project)
  - 3GPP2 is the standardization group for IS-95 (CDMA)
- IMT-2000 (International Mobile Telephony 2000)
  - global standard proposed by the **ITU**
- IMT-2000 3G standards :
  - TD-SCDMA
  - CDMA2000
  - W-CDMA



Development ：2G to 3G



WCDMA

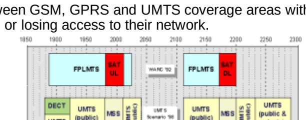


- Wideband CDMA
  - DS-CDMA
  - Use spreading factors 4 - 512 to spread the base band data over ~5MHz band.

Multiple access method	DS-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

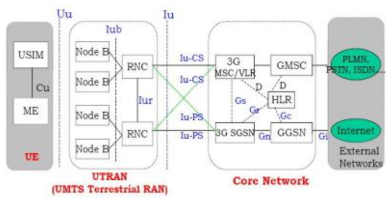
UMTS/WCDMA Features

- 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.



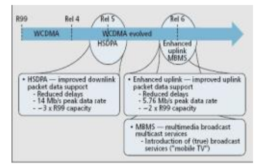
UMTS Architecture

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

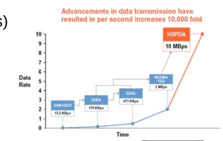


First Step of HSPA - HSDPA

- 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



Enhanced WCDMA - 3.5G HSDPA

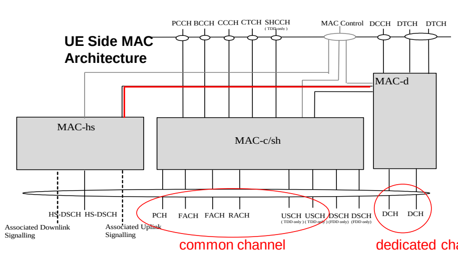
- Defined in 3GPP Release 5.
- Higher data rate：2Mbps~14Mbps

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

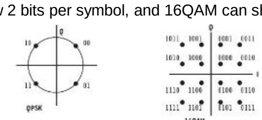
MAC Architecture

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

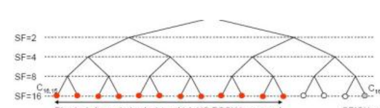


SF and Modulation

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

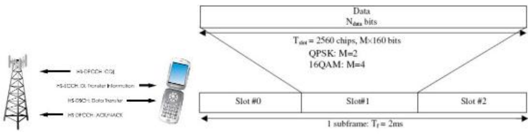


- Channelization code at a fixed SF = 16.



HS-PDSCH

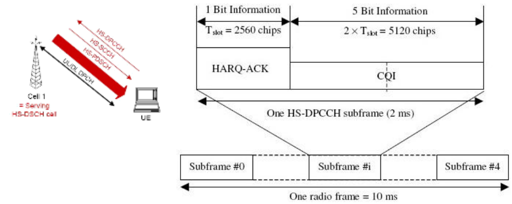
- HS-PDSCH carries the data traffic in terms of MAC-hs PDU.
- Fixed SF=16; up to 15 parallel channels
- 14Mbps = 960 x 15 ~= 14400 kbps



Slot format #I	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ HS-DSCH subframe	N_{data}
0(QPSK)	480	240	16	960	320
1(16QAM)	960	240	16	1920	640

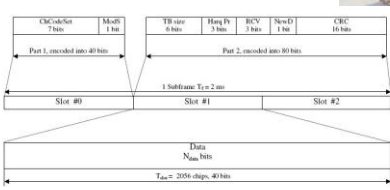
HS-DPCCH

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



HS-SCCH

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

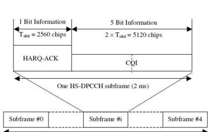


DCH, DSCH and HS-DSCH

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

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.
- $$CQI = \begin{cases} 0 & SNR <= -16 \\ \left\lfloor \frac{SNR}{1.02} + 16.62 \right\rfloor & -16 < SNR < 14 \\ 30 & 14 <= SNR \end{cases}$$



UE Category

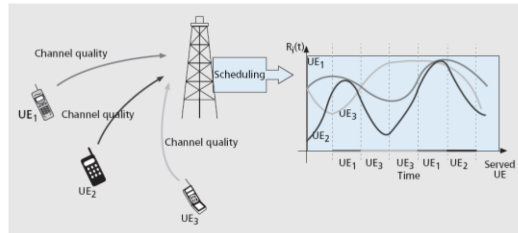
- Classify the UE category base on the capability of UE.

Category	Codes	Inter-TT1	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	20432	172800	QPSK/16QAM	10.2 Mbps
10	15	1	28776	172800	QPSK/16QAM	14.4 Mbps
11	5	2	3650	14400	QPSK only	0.9 Mbps
12	5	1	3650		QPSK only	1.8 Mbps

UE Category 1~6 CQI table

CQI value	Transport Block Size	Number of HS-PDSCH	Modulation	Reference power adjustment Δ	Iir	Xrv
0	N/A	Out of range				
1	137	1	QPSK	0	9600	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	1483	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		

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



Round Robin vs. Proportional Fair Scheduler

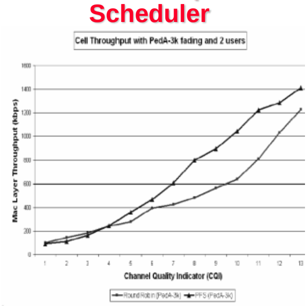
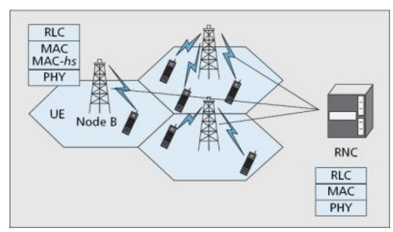
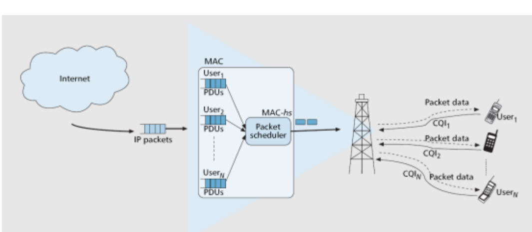


Fig. 1. Performance comparison between Proportional Fair Scheduler and Round Robin in lab, in a low mobility scenario (Ped A)

Scheduling from RNC to Basestation (Node B)



Packet Scheduler Model in HSDPA



Performance of HSDPA, IEEE VTJ 2007

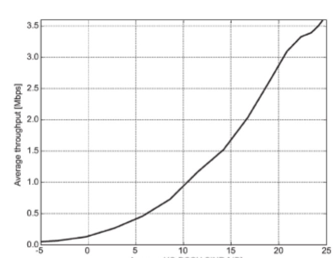


Fig. 5. Single-user HSDPA throughput as a function of the average HS-DSCH SINR.

DCH vs HSPDA

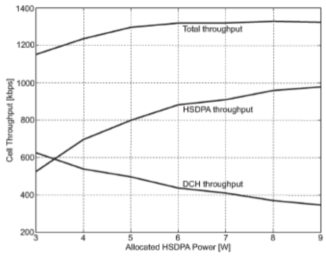
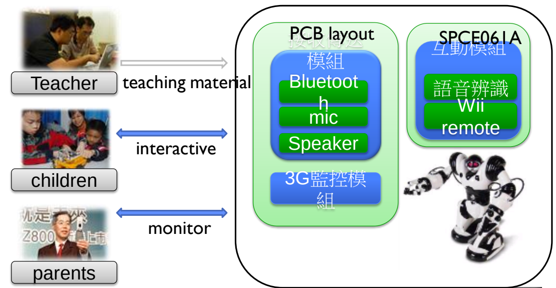
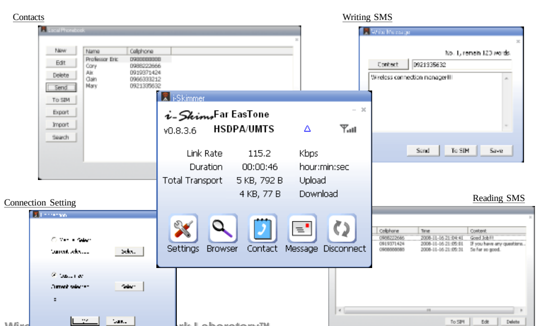


Fig. 7. Average cell throughput versus the allocated HSDPA power. PF scheduling is assumed, with five HS-PDSCH codes and six HSDPA users per cell.

System Architecture



Interface and Use Scenario



Interface and Use Scenario