Packet data capacity in WCDMA networks

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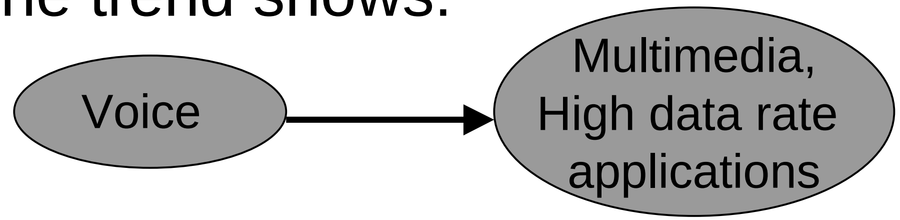
Outline

- Background
- Capacity of WCDMA networks
- Investigation of adaptable date rate’s impact on system capacity
- Compare packet scheduling algorithms
- Conclusion and further work

Background

- WCDMA networks fulfill the 3G system requirements
- The trend shows:



- 3G goal: a large and rich mix of innovative and advanced services.
- **The analysis of network capacity** in order to support these services would be one important aspect of network dimensioning.

Capacity characteristics of WCDMA networks (1/2)

- Dynamic

Admission, QoS control

The instantaneous capacity will depend primarily on the following factors:

1. *QoS requirement of services*
2. *Instantaneous user spatial and speed distribution*
3. *Propagation environment*

- Soft

Limited by the amount of interference.

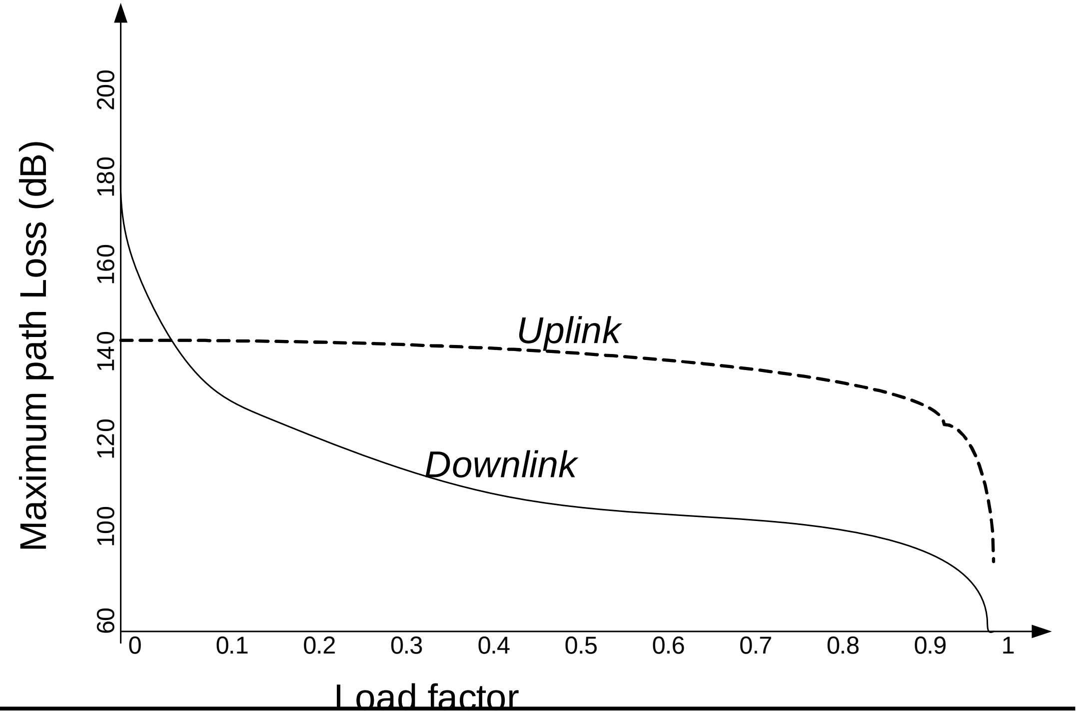
The less interference is coming from the neighboring cells, more channels are available in the middle cell.

Capacity characteristics of WCDMA networks (2/2)

- Tightly coupled with coverage

“cell breathing” stronger for low path loss exponents

- Asymmetric in uplink and downlink



Optimizing the use of available packet capacity

- The system is studied in a given short time interval and the smallest interval for adaptation is one frame. We concern about “Scheduling Process”.

- Simulations are based on Monte Carlo simulation method.

- *<u>The objectives of the simulations are:</u>*

1. Investigation of adaptable date rate's on increasing network capacity (Simulation 1)
2. Comparison of different packet scheduling methods (Simulation 2)

A dynamic network simulator

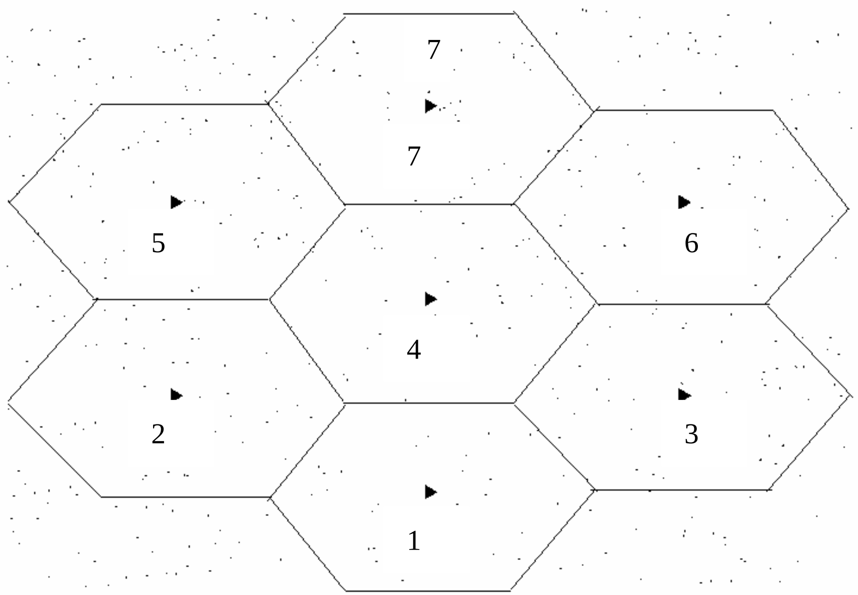
•Users freely move with arbitrary directions

•Radio channel:

“power-law” attenuation,

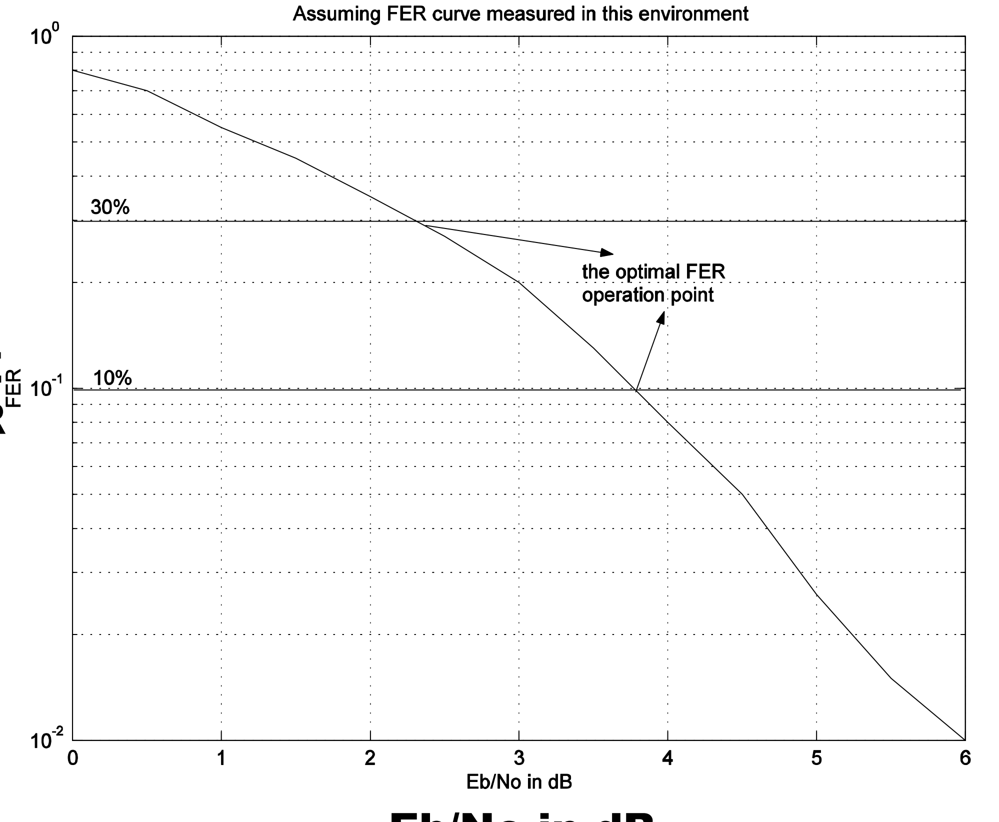
slow and fast fading

Simulation area contains seven cells and moving users in them



Simulation 1:
Adaptable data rate simulation

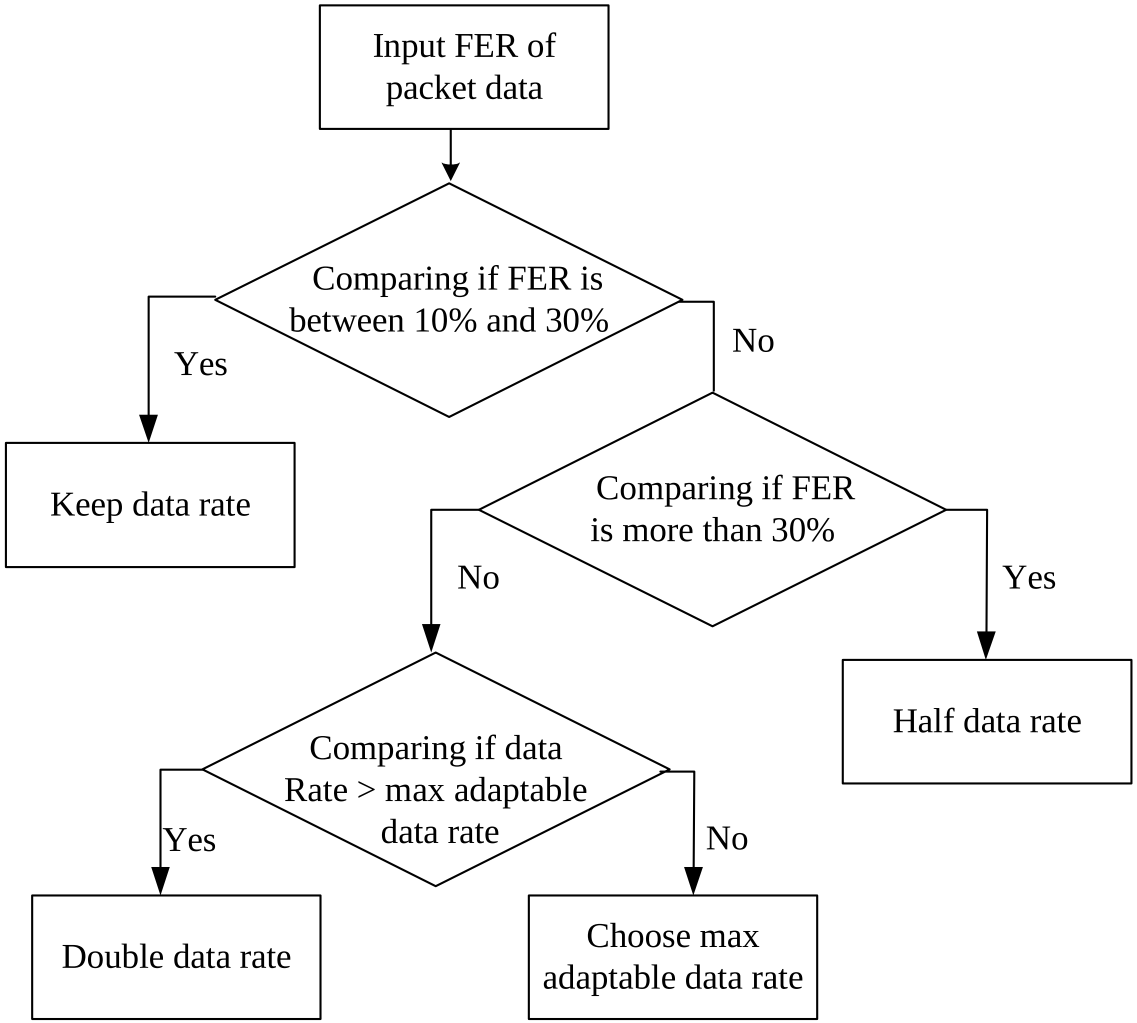
- The FER curve is provided by the link level simulation. The optimal FER operation point is set between 10% and 30%.



FER

Eb/No in dB

The algorithm of adaptable data rate



Scenario1:

Compare the adaptive algorithm with the case when transmitted data rate for a user is constant.

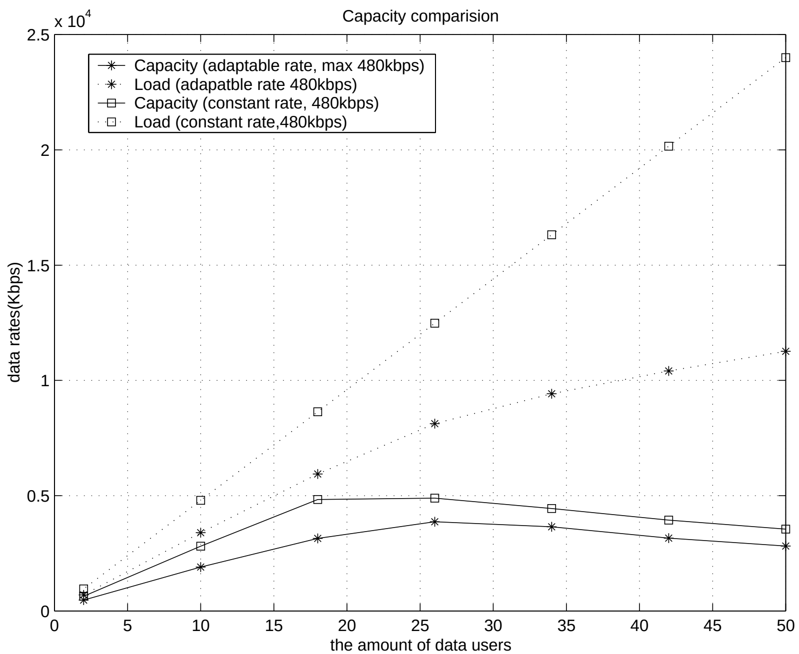
Present how the use of adaptable algorithm impacts the network performance:

1. adaptable data rate: the initial data rate of each user is assumed is 120 kbps. Maximum bit rate is 480 kbps, so adaptable data rates set is {…7.5 15 30 60 120 240 480}

2. constant 480 kbps rate

Simulation results: adaptable data rate and constant data rate

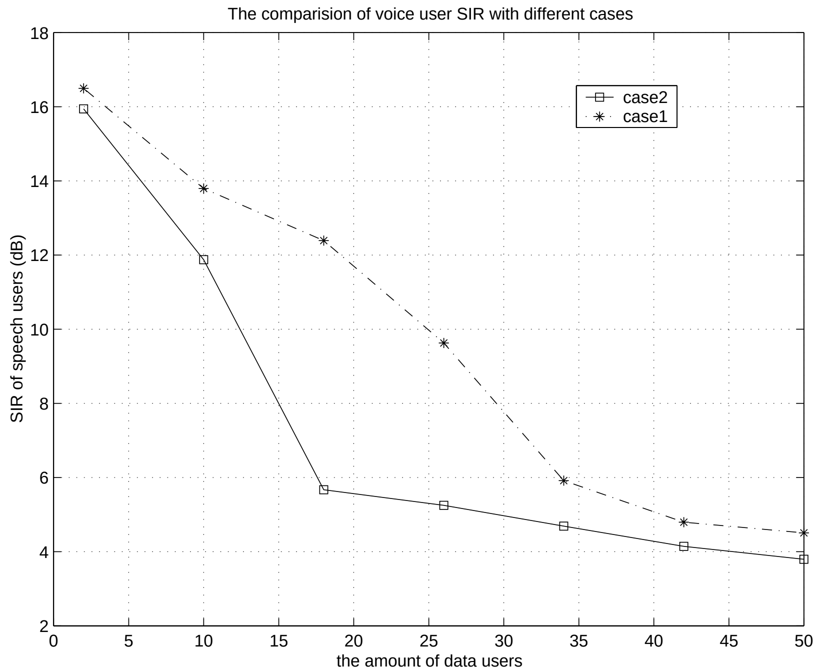
Packet data capacity comparison



Date rate (K bps)

The amount of data users

Voice users' SIR comparison



SIR of voice users (dB)

The amount of data users

Scenario 2

Compare how the algorithm performs when the maximum allowed data rate is changed:

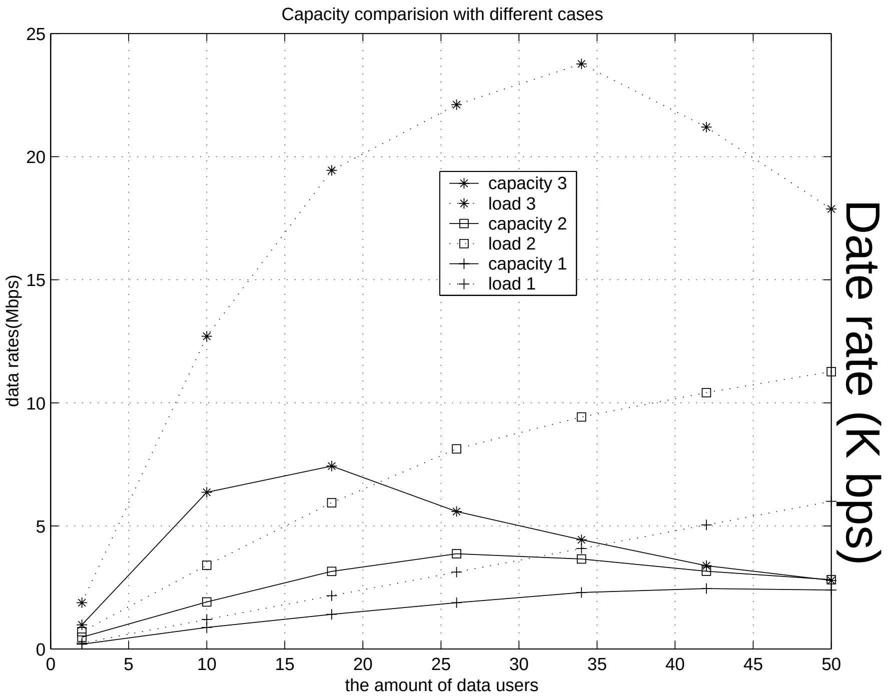
- Case 1: Keep constant data rate 120 kbps, data rate is not adapted

- Case 2: Set up the maximum adaptable data rate is 480 kbps, so adaptable data rates set is {…7.5 15 30 60 120 240 480}

- Case 3: Set up the maximum adaptable data rate is 1920 kbps, so adaptable data rates set is {…7.5 15 30 60 120 240 480 960 1920}

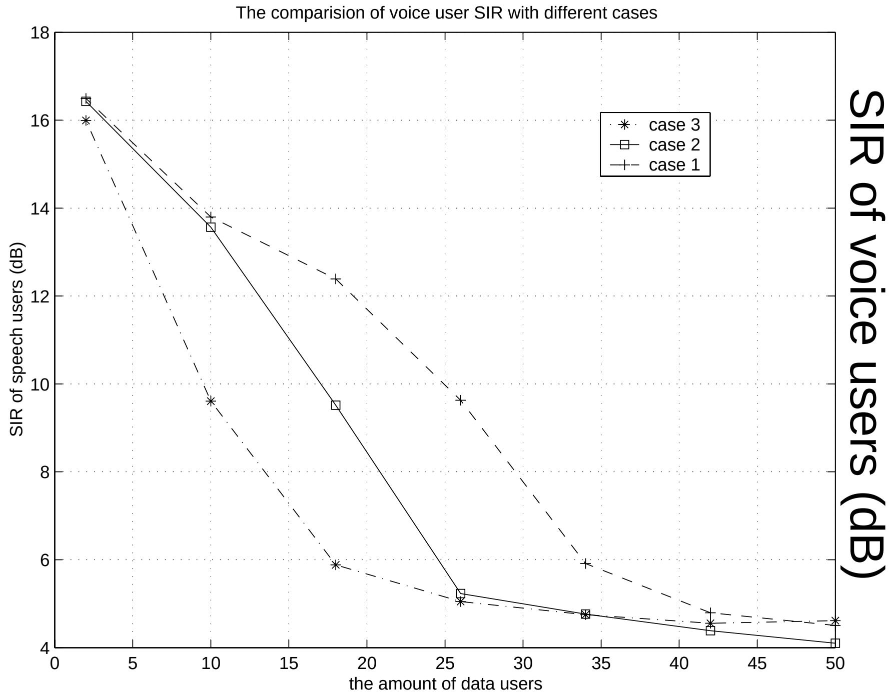
Simulation results: comparisons of three different cases.

Packet data capacity comparison



The amount of data users

Voice users' SIR comparison

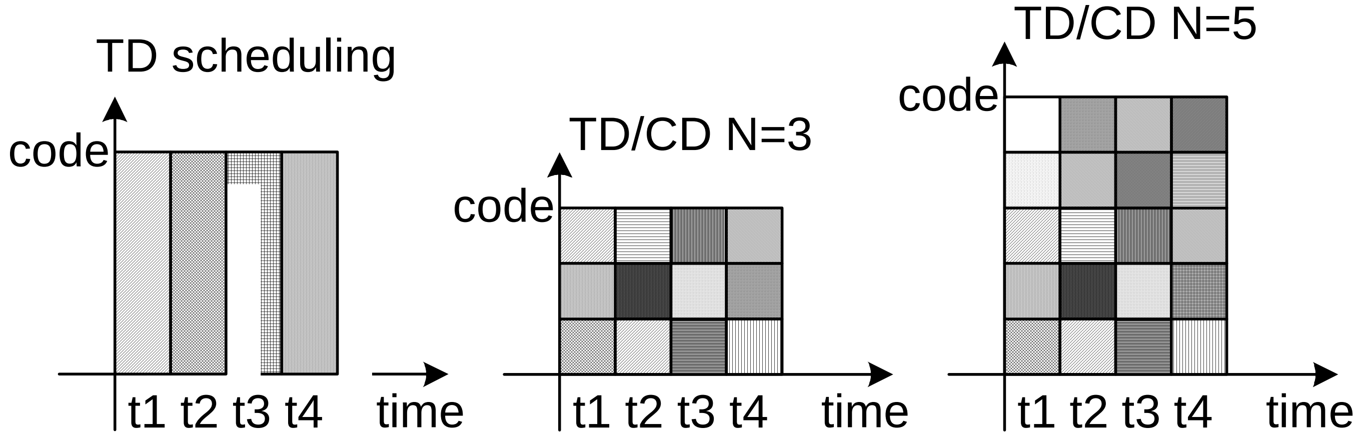


The amount of data users

Simulation 2: packet scheduling methods

- Algorithm 1: TD (Time Division) Scheduling.
- Algorithm 2: TD/CD (Code Division), offer 3 simultaneous channels for packet transmission by code division.
- Algorithm 3: TD/CD, maximum five users' packets can be transmitted simultaneously.

- The scheduling algorithm attempts to allocate the maximum data rate to admitted users.



By simulations and theoretical analysis *(Appendix1)*, it is shown:

Algorithm 1: Time Division Scheduling

- Save power, low packet delay, and less RRM
- Low usage of network resource.

Algorithm 2 & 3: TD/CD Scheduling

- Higher capacity.
- More packet delay. Need code resources and more RRM.

Serving the packet with the largest normalized packet queuing time at first can offer a fairer service to users and give better network performance

$$Normalized\_packet\_queuing\_time = \frac{packet\_queuing\_time}{packet\_length}$$

Conclusion of the thesis

- **Adaptable date rate's impact on system capacity is investigated. One simple dynamic rate control method is proposed.** The result of simulations: when maximum adaptable data rate is set at a higher value, network data capacity can be increased, however, the price is a smaller number of supportable data users.

- **Different packet scheduling methods are analyzed by theory and simulation.**

- **Contribute a preliminary system simulator of WCDMA networks.** An interface between the traffic generation and scheduling process is designed and it awards us with a possibility to study these two processes separately.

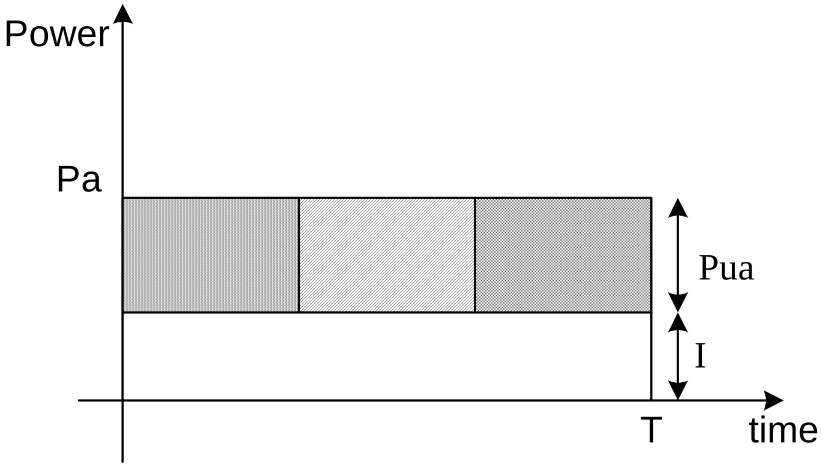
Further work

- The system simulator in this thesis needs to be improved. More features of WCDMA networks can be added so that it can better simulate the real system.
- MATLAB →C (executable efficiency)
- The simulations in this thesis are based on many assumptions. These assumptions are worth studying further.

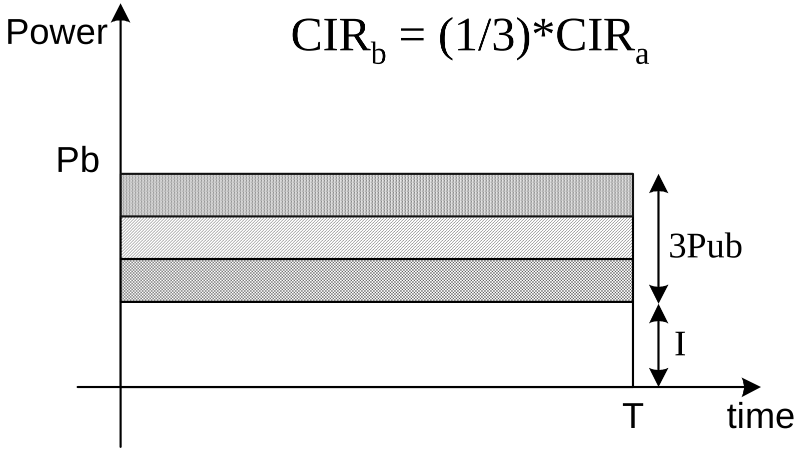
Appendix 1: Analysis of uplink packet scheduling method

Compare the following two cases:

- Time Division Scheduling: Three packets are served one by one in the period T. Each connection has bit rate Ra (Ra=3*Rb).
- Code Division Scheduling : Three packets are transmitted simultaneously in the period T. Each one has the bit rate Rb.



Case 1: TD scheduling



Case 2: CD scheduling

TD scheduling can save power

$$P_{ua} = CIR_a * I$$

$$P_{ub} = CIR_b * (I + 2 * P_{ub}) = \frac{CIR_a}{3} * (I + 2 * P_{ub}) = \frac{CIR_a}{3 - 2 * CIR_a} I$$

The average power level in two cases can be calculated separately as follows:

$$\overline{P}_a = P_{ua} + I = (CIR_a + 1) * I$$

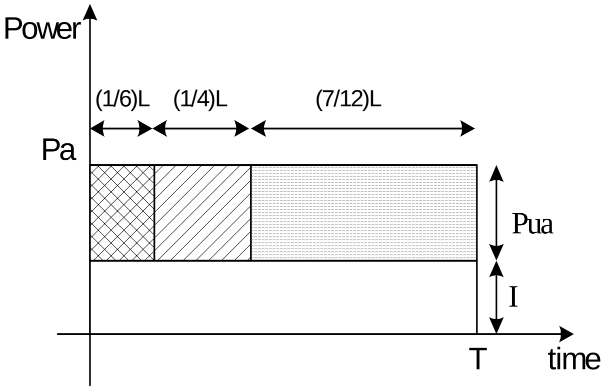
$$\overline{P}_b = 3 * P_{ub} + I = (\frac{3CIR_a}{3 - 2CIR_a} + 1) * I = \frac{3 + CIR_a}{3 - 2CIR_a} I$$

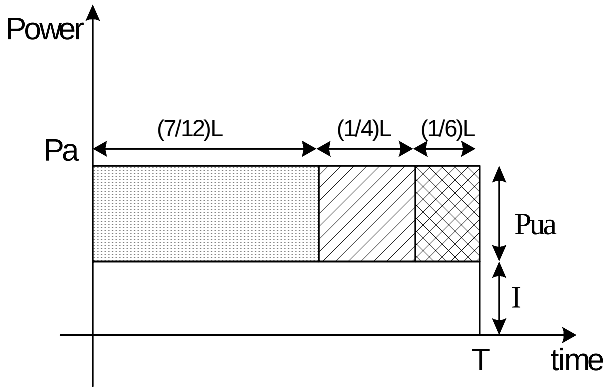
By mathematics transformation, the average power level in case b) can be expressed as follow:

$$\overline{P}_b = \left[(CIR_a + 1) + \frac{2CIR_a{}^2}{3 - 2CIR_a} \right] I = \overline{P}_a + \frac{2CIR_a{}^2}{3 - 2CIR_a} I$$

Serving the different length packets:

the largest normalized packet queuing time at first





$$\overline{D}_1 = \frac{\frac{1}{6}T + (\frac{1}{6} + \frac{1}{4})T + T}{3} = \frac{19}{36}T \qquad \overline{D}_2 = \frac{\frac{7}{12}T + (\frac{7}{12} + \frac{1}{4})T + T}{3} = \frac{29}{36}T$$

Offer service to shorter packets before the longer ones, the packet delay is shorter. Based on the fair policy, we should consider both the packet queuing time and its length:

$$Normalized\_packet\_queuing\_time = \frac{packet\_queuing\_time}{packet\_length}$$

Appendix 2: " Packet scheduling methods" simulation

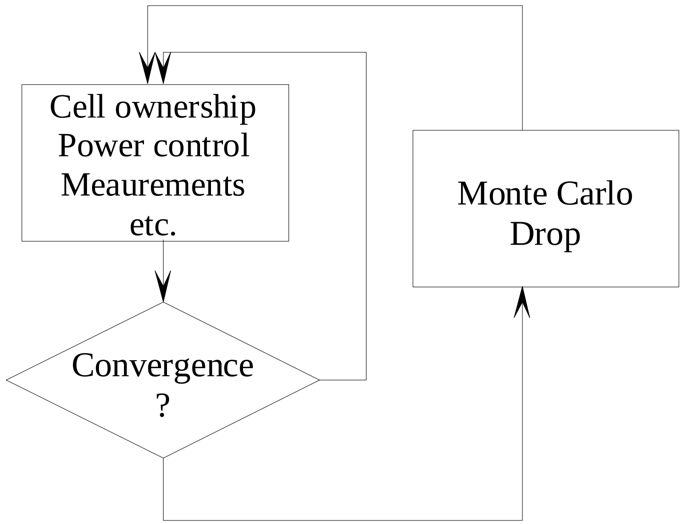
The parameters of network performance

- **Data rate** is the amount of data transferred between the two access points in a given period time.

- **Capacity** is defined as the data rates received correctly at the destination in a given simulation interval. Usually system capacity is what we concerned. It means the sum of all correctly received users' data rate in the system.

- **Delay** means the time from user's request for transferring packet data to their correct delivery at the base station. In this simulation, we only take transmission time and queuing time account into the delay calculation. Some other delay factor such as terminal processing time is negligible here.

Monte Carlo simulation method

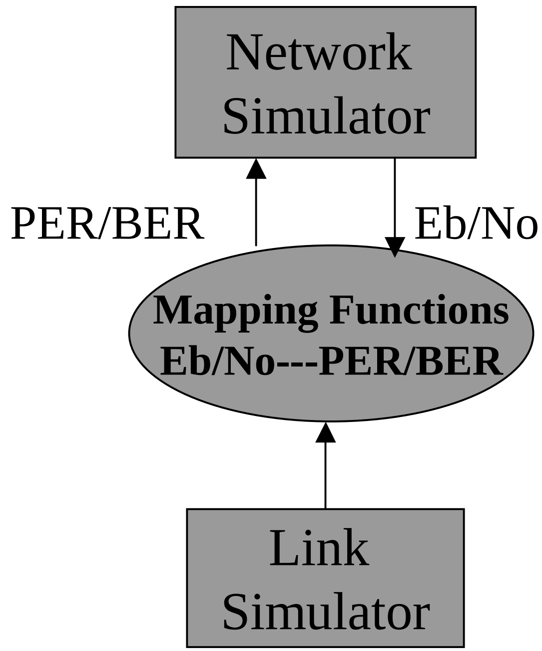


The outer one performs Monte Carlo "drops”.(each drop means a random allocation of mobile users' locations) **The inner loop** is invoked to converge the power control processes in the end of this loop, **one stable system** condition is reached for the geographic configuration of mobiles corresponding to the current loop. For each drop, a series of processes simulating network operation are executed. Sufficient **snapshots** generated can allow the compilation of significant **statistics** on the network performance.

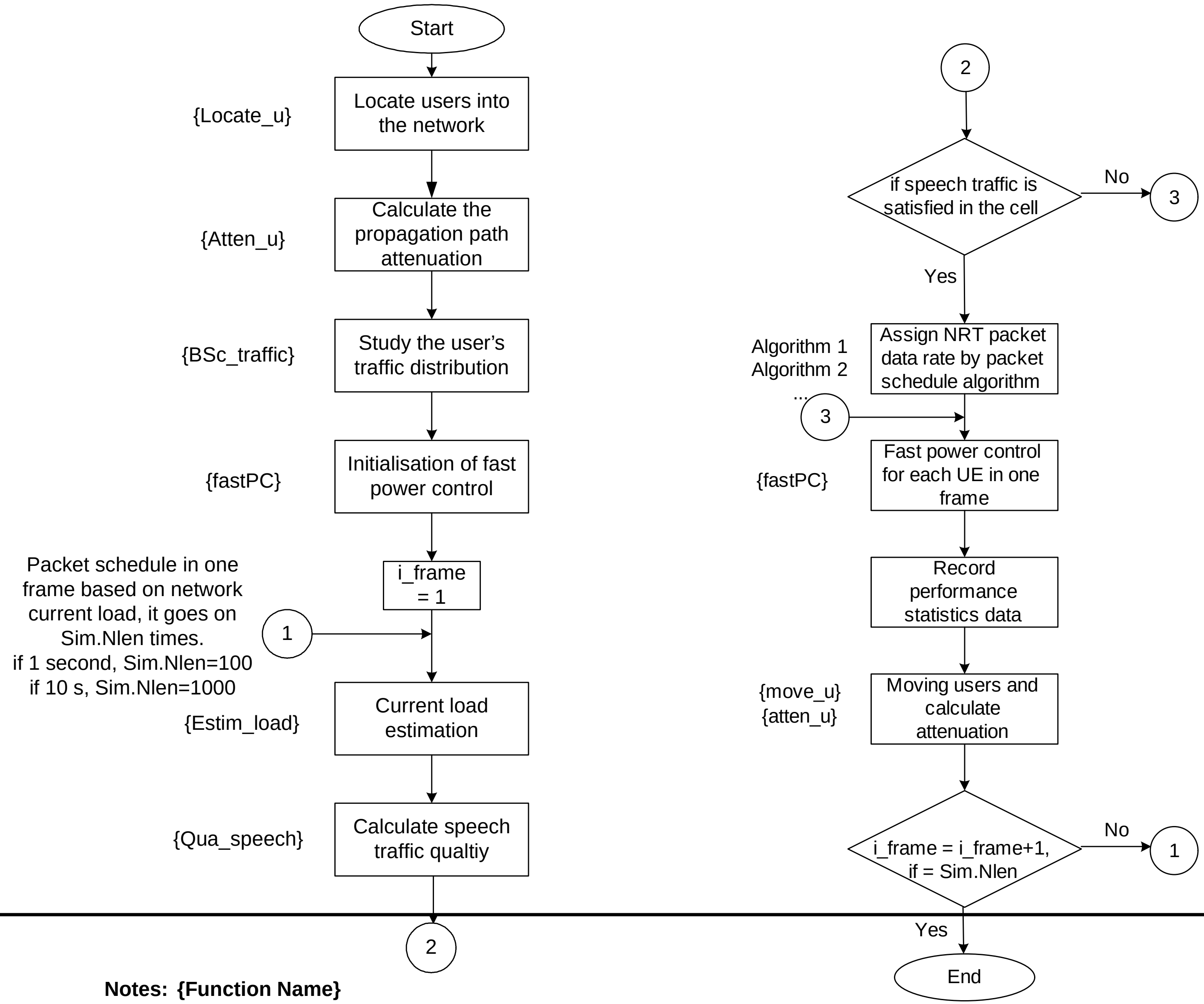
Mapping function------a key input to simulator

- Combine the link level simulation and network level simulation
- Estimate the physical layer function
- In the actual network, it depends on many factors, including :

1. user’s moving speed,
2. cell geometry,
3. receiver performance,
4. coding method.



The flow chart of "packet scheduling method simulations"



Notes: {Function Name}

The parameters of uplink packet data capacity simulations

Site Plan		
Number of cells	NrBS	7
The total amount of users in the system	NrU=NrBS * Users_per_BS	7*(Nr_speech+ Data_active)
Radius of cell	R_cell	50m
Assumed coverage area		$250*260m^2$
WCDMA System parameters		
Chip rate	W	3840 Kcps
Maximal MS TX power	Pmax	1W
Total thermal noise (kTB)	Noise	$10^{-13.7}$ W
Power control step size	PCstep	1 dB (10^0.1)
Power control bits error ratio	PCerr_ratio	2%
Time interval (Power control step)	DeltaT	$6.67*10^{-7}$ S (1/1500 kHz)
Propagation data		
Path loss exponent	att_order	- 3
Standard deviation value for slow fading	slow_fading_std	8
User characteristics		
Direction of user	Users.direct	Uniform Distribution on $[0, 360]^o$
The maximum moving speed of users	Speed_move	Variable (eg, 20 km/h)
Target SIR (E_b/N_o) of speech and data (for PC process)	SIRtarget	3 dB
The average number of speech user per cell	Nr_speech	Variable (eg, 30)
Information rate (speech)	R_speech	12.2 kbps
Packet maximal data rate	Rmax_data	Variable (e.g., 144 kbps)
Size of one packet	Packet_size	15 timeslots (one frame)
Simulation loop control		
The number of iterations in one run	Nlen	100

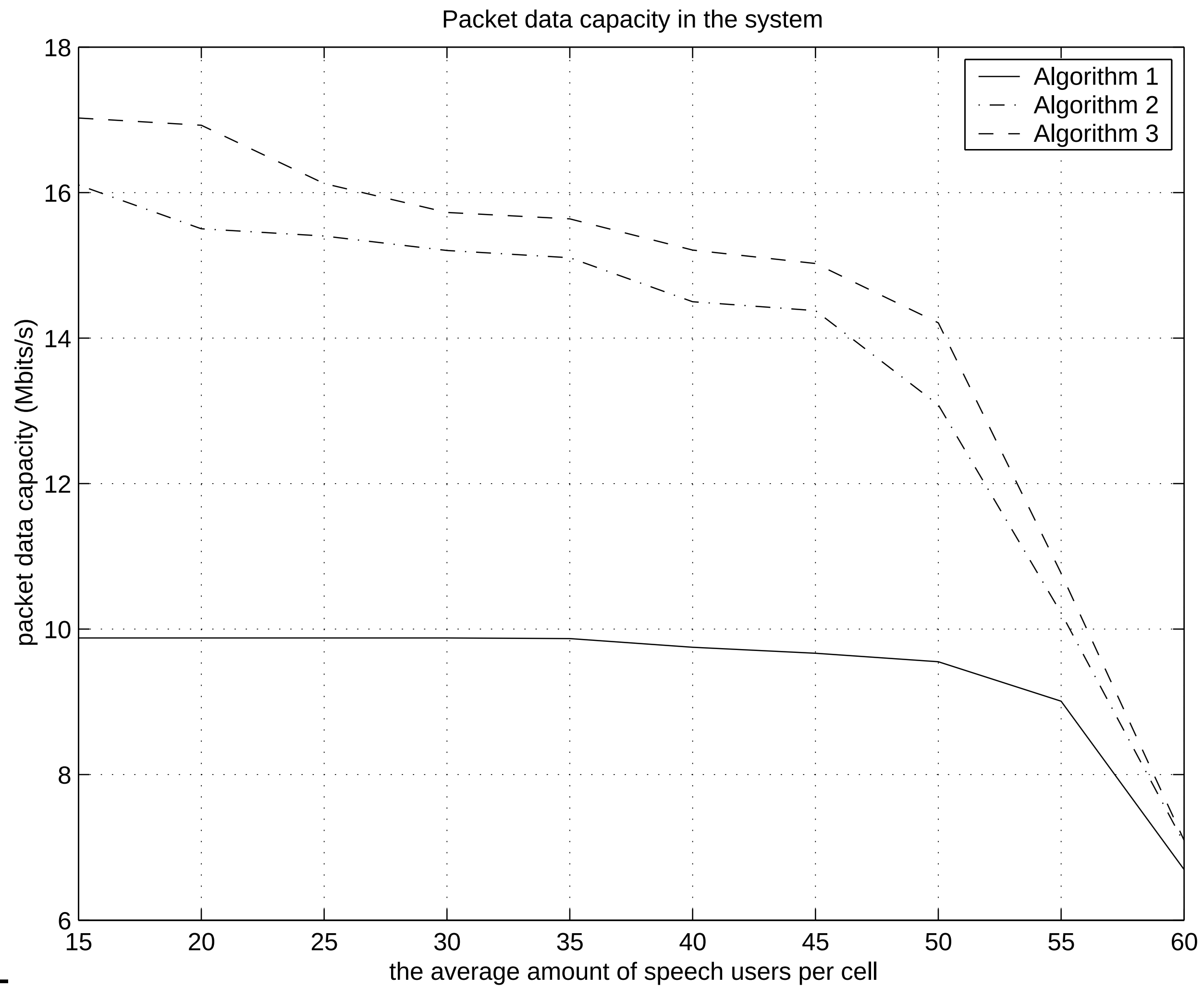
Simulator properties (1/2)

Packet scheduling method	The data rate of one user can be limited. In this simulation, TD/CD mixed scheduling method is selected. There are N parallel codes and N packet users can be served simultaneously. TD method can be looked as N=1.
WCDMA dynamic feature simulation	Consider the user's instantaneous interference to other users in the cell. The interference sources from other cells at the previous time are considered.
Simulation environment	Seven omni-directional BS covering the simulation area (See Appendix 2). Radius of a cell is 50m. The channel model contains slow, fast fading and power law attenuation..
The number of users in the network	In average of 20 active data users per cell.
Simulation period	One snapshot of Monte Carlo simulation simulates 10 seconds' packet data transmission

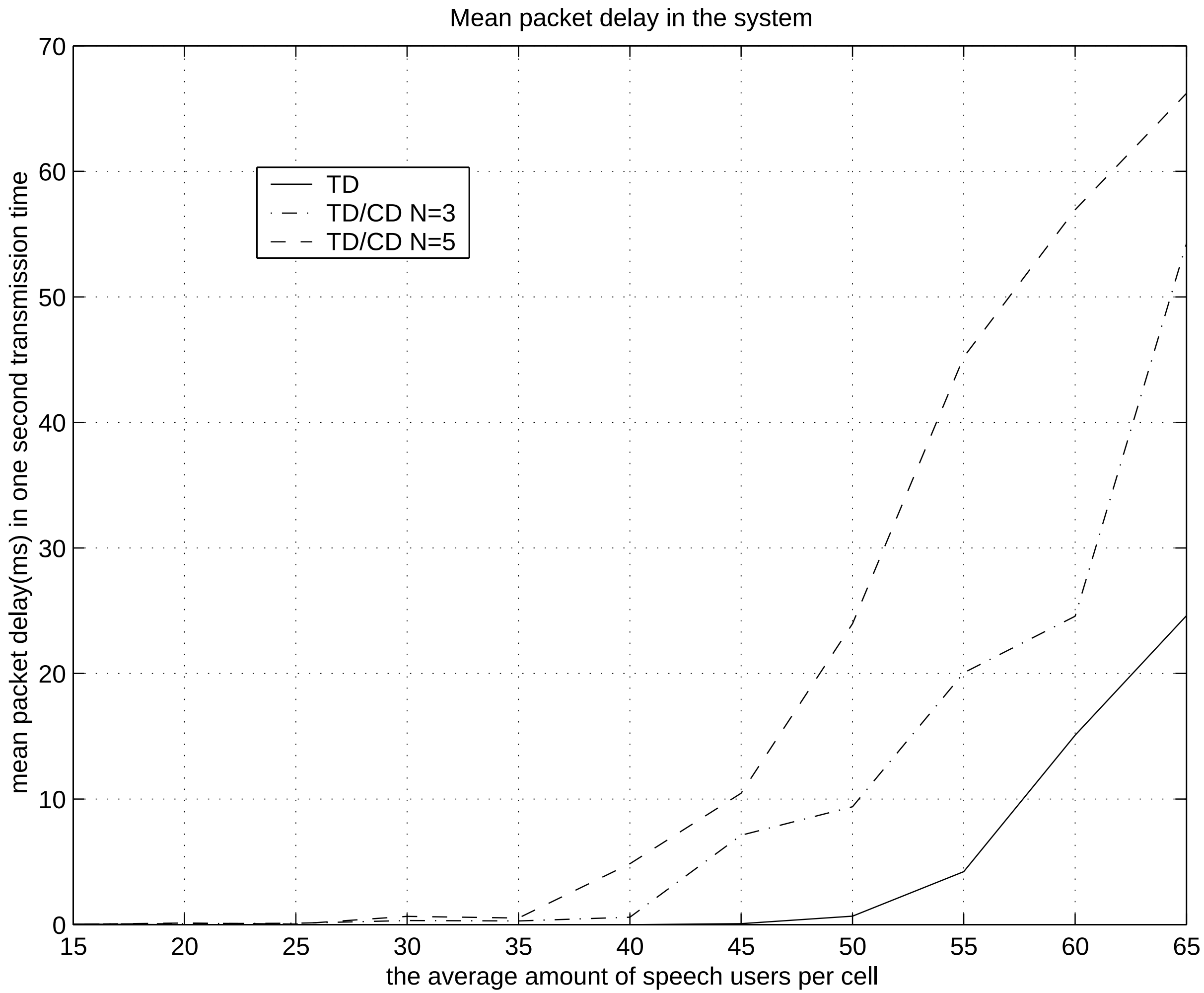
Simulator properties (2/2)

Rate adaptation	The user's data rate is allocated based on the interference level in the network.
The packet length of data user at a time	We assume the packet length is one frame, which is 10 ms. The amount of bits in the packet depends on its data rate.
Queuing strategy	The data buffer is assumed to be full and there is always available packet for transmission.
Packet waiting method	When the packet of one user cannot be successfully received, it needs to wait till this user's turn comes again and then retransmits error packet.
Power control	No uplink outer loop PC is used, target *SIR* (Eb/No) is fixed. Fast closed power control is used here. Its use is based on the measured *CIR* value. The probability of wrong power control operation is 2%.

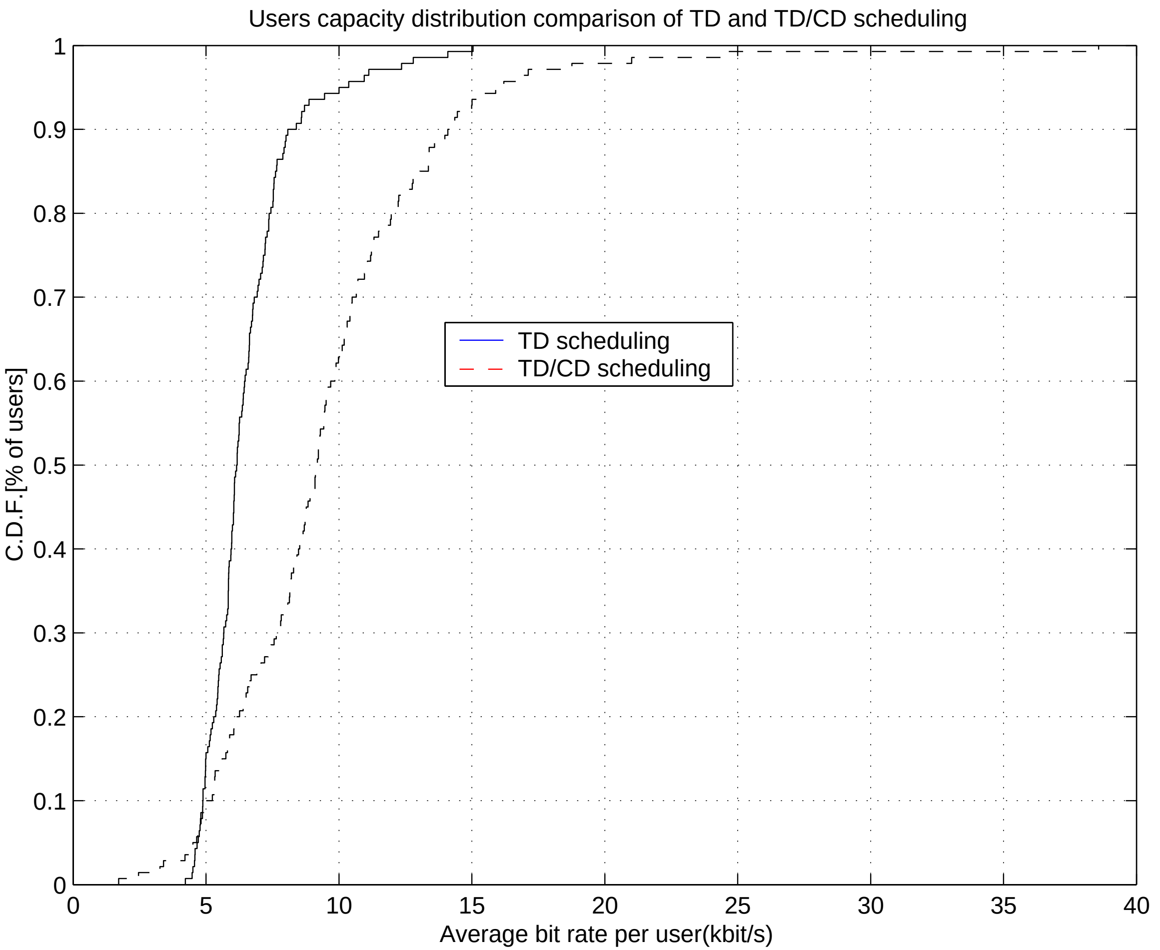
Comparison of packet data capacity in the system



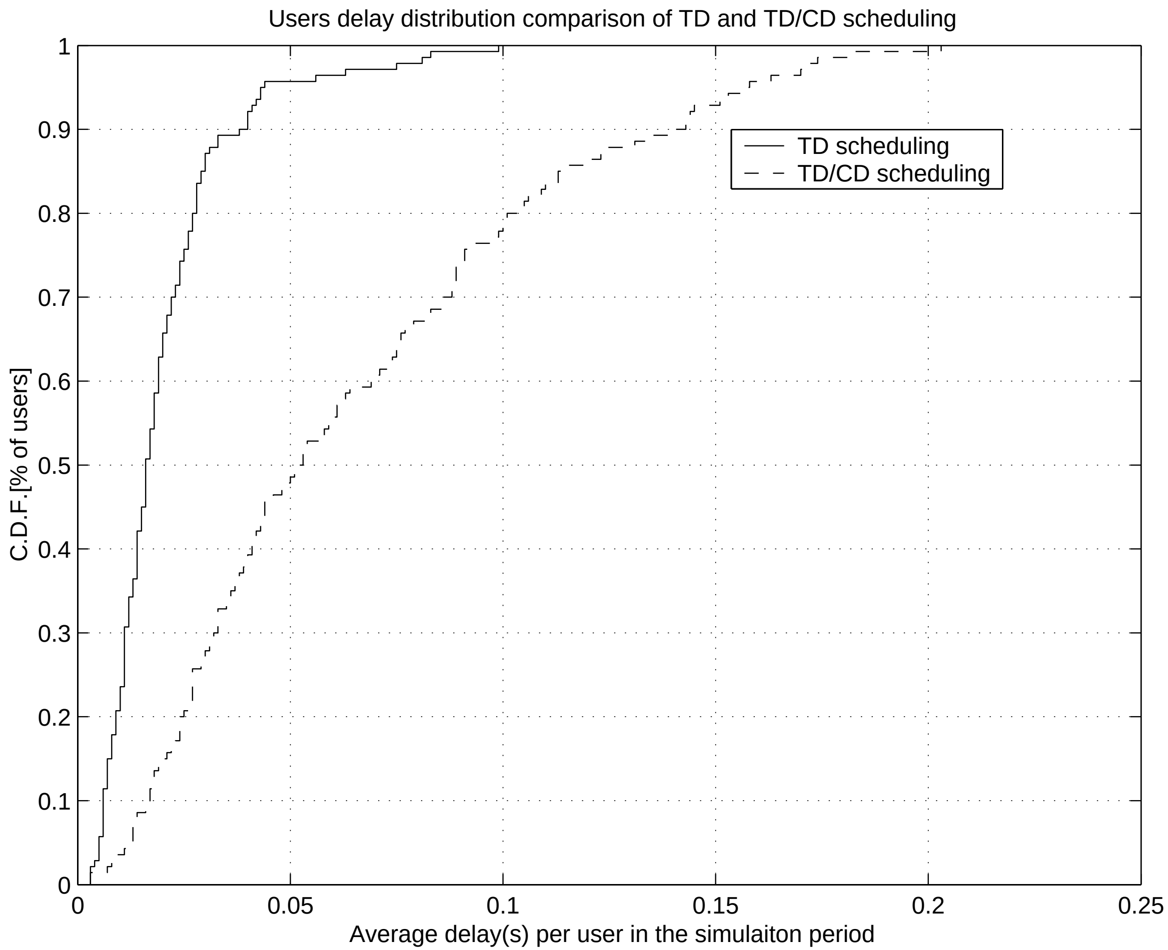
Comparison of mean packet delay in the system



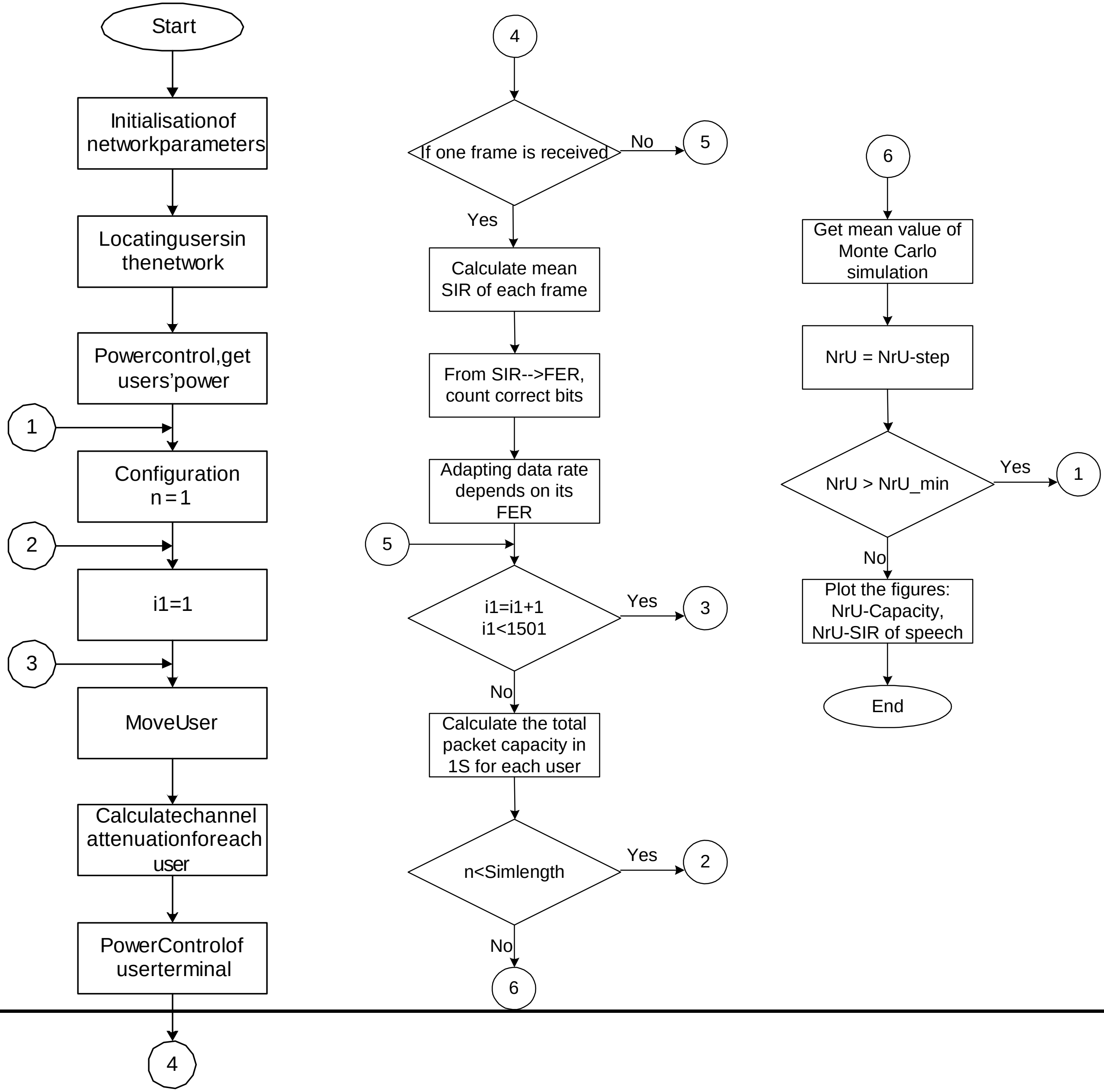
C.D.F of user capacity



C.D.F of user delay



Flow Chart of “ADAPTABLE DATA RATE SIMULATION”



Appendix 3: others

Non real time (NRT) packet service

UMTS QoS classes

QoS class	Applications	Delay	Buffering	Nature of traffic	Guaranteed bit rate
Conversational	Voice, video-telephony, video games	Minimum fixed delay	No buffering	Symmetric traffic	Guaranteed bit rate
Streaming	Streaming multimedia	Minimum variable delay	Buffering allowed	Asymmetric traffic	
Interactive	Web browsing, network games				No guaranteed bit rate
Background	Background download of emails	Big variable delay			

- Bursty, bit rate variable.
- tolerate longer delay.
- low delay sensitivity.

Soft capacity concept

$$Soft\_capacity = \frac{Erlang\_capacity\_with\_soft\_blocking}{Erlang\_capacity\_with\_hard\_blocking} - 1$$

- Soft blocking capacity: limited by the amount of interference in the air interface.

- Hard blocking: limited by the amount of hardware, the amount of codes, output power limitation

- Soft capacity has no single fixed value. The less interference is coming from the neighboring cells, more channels are available in the middle cell.

System pole capacity analysis (1/2)

Assumptions such as below:

- Uplink limited system capacity
- MS unlimited PC range
- Spatially uniformly distributed traffic
- Ratio of in-cell interference to total interference (F factor) is constant
- Eb/No target is the same for all UEs in the network
- Activity factor V is the same for UEs

$$\frac{S}{N} = \frac{P_{mk} L(d)}{I_{in} B + I_{out} B + kTB} \rightarrow P_{mk} L(d) = \frac{S}{N}\left[(I_{in} + I_{out})B + KTB\right]$$

$$F = \frac{I_{in}}{I_{in} + I_{out}} \rightarrow I_{in} + I_{out} = \frac{I_{in}}{F}$$

$$I_{in} = \frac{P_{mk} L(d)(NrU - 1)V}{B} \rightarrow NrU - 1 = \frac{I_{in} B}{P_{mk} L(d) V}$$

$$\Rightarrow \quad NrU = \frac{F}{V \frac{S}{N}} + 1 - \frac{kTBF}{P_{mk} L(d) V}$$

When the third term of becomes very small and the capacity of the system becomes limited by the F factor, the activity ratio V and the signal-to-noise ratio. This limiting value is called ’pole capacity’.

System pole capacity analysis (2/2)

- The assumptions for deducing system pole capacity formula are obviously unreasonable for a real network. (downlink limited, mobiles power limited, traffic distribution not uniformly spatially distributed)
- All the limiting factors for the system capacity are variable. (The F-factor vary according to mobile subscriber densities, BTS placements and system loading. Voice activity is a function of dialect, service types etc. And finally the E_b/N_o requirement is the function of mobile speed, multi-path environment etc)

How to analyse system capacity effectively & efficiently?

→ ***Simulation based approach***