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Design Methodology of System-Level Simulators for Wideband CDMA Cellular Standards

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광대역 CDMA 셀룰러 표준을 위한 시스템 수준 시뮬레이터의 설계 방법론

박성경

ABSTRACT

This tutorial paper presents the design methodology of system-level simulators targeted for code division multiple access (CDMA) cellular standards such as EV-DO (Evolution-Data Only) and broadcast multicast service (BCMCS). The basic structure and simulation flow of system-level simulators are delineated, following the procedure of cell layout, mobile drops, channel modeling, received power calculation, scheduling, packet error prediction, and traffic generation. Packet data transmissions on the forward link of CDMA systems and EV-DO BCMCS systems are considered for modeling simulators. System-level simulators for cellular standards are modeled and developed with high-level languages and utilized to evaluate and predict air interface performance metrics including capacity and coverage.

Key words : System-level simulator, BCMCS, packet data, packet error, scheduling, cellular

요 약

이 논문에서는 EV-DO나 브로드캐스트 멀티캐스트 서비스와 같은 CDMA 셀룰러 표준을 목표로 하는 시스템 수준 시뮬레이터의 설계 방법론을 소개한다. 셀 레이아웃, 모바일 분포, 채널 모델링, 수신 전력 계산, 스케줄링, 패킷 에러 예측, 트래픽 생성 등의 절차를 따라 가면서, 시스템 수준 시뮬레이터의 기본 구조와 시뮬레이션 흐름을 기술하였다. 시뮬레이터를 모델링하기 위해, CDMA 시스템과 EV-DO 방송 시스템의 순방향 링크에서의 패킷 데이터 전송을 고려하였다. 셀룰러 표준을 위한 시스템 수준 시뮬레이터는 상위 수준 언어로 모델링 및 개발 되었고, 용량과 커버리지를 포함한 에어 접속부 성능 지표들을 계산 및 예측하는 데에 이용되었다.

주요어 : 시스템 수준 시뮬레이터, 브로드캐스트 멀티캐스트 서비스, 패킷 데이터, 패킷 에러, 스케줄링, 셀룰러

1. Introduction

The aim of system- or network-level simulators for cellular standards is to predict the air link performances such as capacity and coverage, prior to field experiments. For the voice service, capacity refers to voice capacity which is derived from the outage probability while for the data service, capacity refers to the throughput of data. For performance evaluation, the cellular system under consideration is modeled and dynamically simulated for some simulation time with related parameters and output metrics updated and averaged periodically. System-level simulators are modeled with high-level languages such as C and include the interactions between base stations and mobiles. The channel is modeled at the physical layer and other parts are modeled also at the medium access control (MAC)

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layer and above. System-level simulators include desired power and interference calculation, scheduling, power control, and traffic generation on a macroscopic scale because interactions between a host of base stations and mobiles are considered on the modeled multi-cell topology.

In this paper, we describe the design methodology of system- or network-level simulators for cdma2000 cellular standards. The design principles and considerations of system-level simulators are described with the forward-link packet data transmission in cdma2000 and data transmission in EV-DO (Evolution-Data Only) broadcast multicast service (BCMCS) taken as design examples. The design methodology is also applicable to other cellular standards such as wideband code division multiple access (WCDMA), with slight modifications according to the relevant standards.

The following section of the paper presents the basic structure and simulation flow of system-level simulators for cellular standards, based on [1]. The section is subdivided into subsections which address the outline of the overall structure of system-level simulators, cell deployment, mobile drops, propagation loss modeling, channel modeling, active set decision, pilot *Ec/Io* calculation, scheduling, packet error prediction by link-level results, traffic generation, and higher-layer modeling. Then followed are simulator design examples based on the forward-link packet data transmission in cdma2000 and EV-DO BCMCS systems and concluding remarks of the article.

2. Basic Structure and Simulation Flow

2.1 Outline of the Overall Structure

The structure of a system-level simulator may be decomposed into some parts: the part of cell layout and mobile drops, the part of propagation loss and channel modeling, the part of active set decision and pilot *Ec/Io* calculation, the part of scheduling on the base station side, the part of packet error prediction, and the part of traffic generation and higher-layer modeling including the modeling of the transmission control protocol (TCP) layer. In this article, the basic modeling and related parameters of system-level simulators are determined according to the evaluation methodology [1] and [2].

2.2 Cell Deployment and Mobile Drops

In general, the layout of cells has a two-tier, nineteen-cell, fifty-seven-sector topology, as illustrated in Fig. 1. Each cell is of a hexagon type and consists of three sectors. Each base station is located at the center of the cell and the distance between two adjacent base stations is nominally set to 2.5km. For positioning the nineteen cells (using a high-level language), the center point of the center cell is taken as the origin of Cartesian (or rectangular) coordinates and center points of all other cells are expressed in terms of the cell radius, $cell\_radius \times cos(\pi/3)$, and $cell\_radius \times sin(\pi/3)$.

Mobile may be dropped onto the cell layout using the following steps. In the first step, the location of a mobile within sector 0 of the center cell is stochastically determined. In other words, with the origin at the center point of the center cell, a mobile is dropped, in a random and uniform manner, onto sector 0 whose five-side region is determined by five inequalities. The mobile are to be dropped more than 35m away from the origin, which is an additional condition. In the second step, after the location of the mobile within

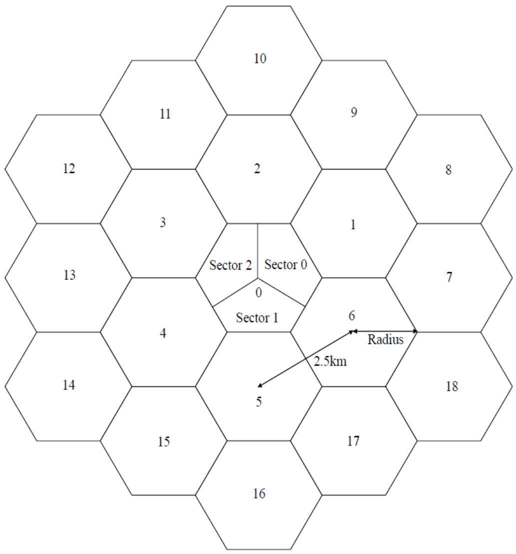


Fig. 1. Cell layout topology

sector 0 of the center cell is determined, one sector is randomly selected among sectors 0, 1, and 2 of the center cell. This is done by randomly generating a number among 0, 1, and 2. If 1 is generated, the location of the mobile is rotated by $2\pi/3$ radian. If 2 is generated, the location of the mobile is rotated by $4\pi/3$ radian. If 0 is generated, the mobile location determined in the first step does not change. After the sector location of the mobile within the center cell is determined, the final step is to randomly select a cell among the nineteen cells. If, for instance, cell 1 is selected, the mobile location determined in the second step is shifted by $cell\_radius+cell\_radius\times\cos(\pi/3)$ in the x direction and $cell\_radius\times\sin(\pi/3)$ in the y direction. In other words, the mobile is shifted in the x direction by the x coordinate value of the center point of cell 1 and shifted in the y direction by the y coordinate of the center point of cell 1. The cell location of the mobile within the nineteen-cell topology is determined in this manner. Thus, the mobile location on the cell layout is nominally determined by following the above three steps repeatedly for each mobile. More elaboration on mobile drops and the total number of mobiles dropped on the layout of cells is addressed in subsection 2.4.

2.3 Propagation Loss and Channel Modeling

Propagation loss is different from fading in that the former is a slow, long-term loss and the latter is a fast, short-term factor. Propagation loss is typically expressed as $d^m 10^{0.1z}$, where d is the path distance between base station and mobile, m is an index normally in the range of -4 to -3, and z is shadowing loss in dB. Thus, considering antenna loss as well, propagation loss in dB is expressed as the sum of path loss, shadowing loss, and antenna loss, provided that all loss terms are in dB.

The air propagation model between base station and mobile is based on Modified Hata Urban Propagation Model at 1.9GHz. Assuming the base station antenna height is 32m and the mobile antenna height is 1.5m, the path loss model is formulated as $-28.6-35\log_{10}d(dB)$,where d is the distance between base station and mobile. Implied in the formula is that the index m is set to -3.5. The value of d is assumed to be larger than 35m, as mentioned in subsection 2.2. In other words, if a mobile is dropped to make the value of d less than or equal to 35m, the mobile should be re-dropped until the value of d is larger than 35m.

Log-normal shadowing in dB has the mean of 0 and the standard deviation s of 8.9dB and is generated independently per mobile. Shadowing loss z_i (dB) (which has normal or Gaussian distribution) in conjunction with the i-th base station consists of two terms: a Gaussian shadowing term x(dB) that is related to the vicinity of each mobile, thereby being independent of base stations, and a Gaussian shadowing term x_i (dB) that is different from base station to base station (or from cell to cell). Consequently, shadowing loss is formulated as follows: $z_i=ax+bx_i$, where $a^2+b^2=1$, the averages of z_i, x, and x_i are all 0, the variances of z_i, x, and x_i are all s^2, the correlation between x and x_i is 0 for all i, and the correlation between x_i and x_j is 0 for all $i\neq j$. Since the correlation coefficient between two base stations is assumed to be 0.5 [1], the average of $z_i\times z_j$, divided by s^2, is equal to 0.5, namely, a^2 equals 0.5. From the relation that $a^2+b^2=1$, b^2 also equals 0.5.

Antenna loss is represented as the sum of antenna pattern loss, overall base station antenna gain, mobile antenna loss, and other loss. Fig. 2 illustrates the antenna directions for each cell and the antenna pattern for each sector. The horizontal angle of 0° on the right half of Fig. 2 corresponds to the direction which each arrow on the left half of Fig. 2 points to. The more the horizontal angle is apart from the center (0°), the larger becomes the magnitude of antenna pattern loss, but with a limit (-20dB). The antenna pattern loss (dB) in Fig. 2 is formulated as $\neg\min\{12(\theta/\theta_{3dB})^2,\ 20dB\}$ where $\min\{a, b\}$ is defined the minimum value between a and b, θ ranges from -180° to 180°, and θ_{3dB} is the 3dB beamwidth which is equal to 70°. Overall base station antenna gain is the sum of base station antenna gain (17dB) and cable loss (-2dB). Mobile antenna loss is assumed

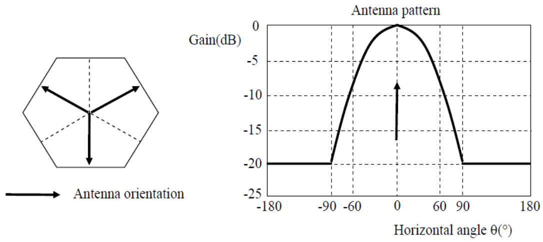


Fig. 2. Antenna direction for each cell and antenna pattern for each sector

to be -1dB and other loss is set to -10dB.

Channel is modeled as a fast fading channel with single/multiple path(s) or finger(s), based on Jakes and Ricean models. The channel is classified into five models, models *A*, *B*, *C*, *D*, and *E*, with the assignment probability 0.3, 0.3, 0.2, 0.1, and 0.1, respectively, in case of the mixed or composite channel model environment. Under this environment, a uniform random number is generated between 0 and 1 for a mobile and if the number is between 0 and 0.3, model *A* is assigned to the mobile. If the number is between 0.3 and 0.6, model *B* is assigned to the mobile and if the number is between 0.6 and 0.8, model *C* is assigned to the mobile. If the number is between 0.8 and 0.9, model *D* is assigned to the mobile and if the number is between 0.9 and 1, model *E* is assigned to the mobile. Under the single fixed channel model environment, all mobiles dropped on the cell layout are assumed to have a fixed channel model, one of the five channel models.

Models *A*, *B*, *C*, and *D* are based on Jakes fading channel [3] and model *E* is based on Ricean fading channel (with Ricean factor *K* set to 10dB). Models *A*, *D*, and *E* have a single path or finger, model *C* has two paths, and model *B* has three paths. Models *A* and *D* are assumed to have a captured power ratio of about 0.9863 and an uncaptured power ratio of about 0.013 [1]. The captured power ratio means the fractional power recovered (as the desired power) by each finger of the receiver. The uncaptured power is regarded as interference. Model *C* is assumed to have captured power ratios of about 0.8128 and 0.0933 for the two paths and an uncaptured power ratio of about 0.0938. Model *B* is assumed to have captured power ratios of about 0.6855, 0.166, and 0.0676 for its three paths and an uncaptured power ratio of about 0.081. In system-level simulators, the uncaptured power ratio is considered in an additional fictitious path.

Models *A*, *B*, *C*, *D*, and *E* correspond to mobile speeds (km/hour) of 3, 10, 30, 120, and 0, respectively. At a carrier frequency of 2GHz, mobile speeds (km/hour) of 3, 10, 30, and 120 correspond to Doppler frequencies (Hz) of about 5.5556, 18.5185, 55.5556, and 222.2222, respectively. Doppler frequency of 1.5Hz is assumed for model *E*. Fading channels associated with sectors pertaining to the active set (which will be defined in subsection 2.4) are modeled as multipath channels with captured and uncaptured power ratios considered. However, for convenience, channels related to sectors that do not belong to the active set are typically modeled as one path Rayleigh channels with power ratios of 1. For each mobile, each sector, and each path, fading is reset at the initialization stage of a system-level simulation and a sample of the fading process (in the form of complex envelope) is generated every time slot or unit (which is 1.25ms in cdma2000), using the corresponding Doppler frequency, the previous sample value, and the captured/uncaptured power ratio [3].

2.4 Active Set Decision and Pilot *Ec/Io* Calculation

On the forward link, only the center cell (or sector) and the mobiles served by the base station at this center cell (or sector) are of concern in terms of the desired signal, whereas all the other (eighteen) base stations surrounding the center cell are considered to contribute to the interference. The eighteen base stations at the first and second tiers are assumed to operate without power control. (On the other hand, in reverse-link system-level simulators, the serving base station receives the desired signal from the served mobile under consideration and regards signals from all other mobiles as interference.)

On the forward link, the active set of each mobile has at least one sector and at most three sectors as its element(s). Specifically, each mobile calculates the received pilot E_c/I_o from every sector and chooses three sectors with the largest, second largest, and third largest E_c/I_o's. If the sector onto which the mobile is dropped and which belongs to the center cell is not included in these three sectors, the mobile is discarded. Otherwise, the mobile is valid and the active set of this mobile is decided as follows: If the second largest E_c/I_o is smaller than the largest E_c/I_o by over 6dB, the active set has only one sector and the active set size is said to be one (corresponding to no handoff). If at once the second largest E_c/I_o is smaller than the largest by less than 6dB and the third largest is smaller than the largest by over 6dB, the active set size is two (corresponding to 2-way soft handoff). Finally, if the third largest E_c/I_o is smaller than the largest by less than 6dB, the active set size is three (corresponding to 3-way soft handoff).

On the forward link, if a mobile that is dropped on the center sector (sector 0, 1, or 2 in Fig. 1) does not have this sector as one of the three sectors from which the received E_c/I_o's are the largest, then the mobile is discarded and re-dropped. Even a mobile that is dropped on a sector outside the center cell is regarded to be served by a center sector if the mobile has the center sector as its active set. This stems from the random property of shadowing loss term of propagation loss. Mobiles served by the center cell are all included in assessing the forward link performance such as capacity and coverage.

A mobile dropped on the cell layout is normally counted as one mobile if its active set size is one. If, however, its active set size is two, it is counted and regarded as a half mobile and if its active set size is three, it is counted as one third of a mobile. According to this rule, the mobile dropping procedure comes to perfection if the total number of mobiles (practically dropped on the layout of cells) gets close enough to the target number of mobiles for the system-level simulator. In other words, mobile dropping is completed if the difference between the total number of dropped mobiles and the target number of mobiles is less than a given value (which may be chosen as 0.3).

In the forward link system-level simulator, the received pilot E_c/I_o of a given mobile is calculated for every sector. Assuming that the base station transmits at the maximum power of 20W and the pilot power occupies 12.5% of 20W, as in cdma2000, the pilot E_c for a mobile-sector pair equals $20\times 0.125\times\ 10^{0.1\times propagation\_loss(dB)}$ in linear scale. I_o is equal to $I_{or}+I_{oc}+N_0$ where I_{or} is the total received power from all the sectors in the active set, I_{oc} is the total received power from all the sectors not included in the active set, and N_0 is the noise power considering both the mobile noise figure (set to 10dB [1]) and the power spectral density of the thermal noise floor (whose value is -174dBm/Hz). Then, $I_{or}+I_{oc}$ of a given mobile is equivalent to $\Sigma\ 20\times 10^{0.1\times propagation\_loss(dB)}$ over all the sectors and N_0 equals $10^{0.1\times(10-174)}\times 0.001\times 1228800$ for the CDMA bandwidth of 1.2288MHz. In calculating the received pilot E_c/I_o, propagation loss is included and (short-term) fading is excluded. The maximum E_c/I_o achievable, $(E_c/I_o)_{max}$, is present on account of some factors contributing to self interference, I_{self}. This factors include the baseband pulse shaping waveform, radio noise floor, analog-to-digital converter (ADC) quantization noise, and adjacent channel interference whose values in terms of I_{or}/I_{self} (dB) are assumed to be 24dB, 20dB, 31.9dB, and 27dB, [1] respectively, leading to the maximum E_c/I_o achievable of 17.8dB. Consequently, the resulting effective E_c/I_o, $(E_c/I_o)_{eff}$, is expressed as: $1/(E_c/I_o)_{eff}=1/(E_c/I_o)+1/(E_c/I_o)_{max}$ where E_c/I_o indicates the received pilot E_c/I_o and $(E_c/I_o)_{max}$ equals $10^{0.1\times 17.8}$ which is in turn equals about $1/(10^{-0.1\times 24}+10^{-0.1\times 20}+10^{-0.1\times 31.9}+10^{-0.1\times 27})$.

2.5 Scheduling

The forward channel quality (or received forward pilot carrier power to interference ratio) is measured by the mobile each time unit (or slot) and sent on the reverse link from the mobile to the serving base station. After some delay (typically set to two slots), the base station reflects the measured channel quality in scheduling. At the point of transmission completion of a packet or in case that a new packet is generated out of an idle state, the base station determines and selects which mobile it should send data to. Next, the rate at which data are sent to the selected mobile is determined. This mobile selection and data rate determination on the base station side are called scheduling.

Mobile selection is implemented using various methods such as round-robin scheduling, maximum carrier-to-interference (*C/I*) scheduling, and proportional fair scheduling. In round-robin scheduling, mobiles are equal in priority and selected one by one (from the first to the last mobile) at each scheduling point of time. After the last mobile is selected, the first one is again selected at the subsequent scheduling point of time and the selection procedure goes sequentially in the original order. In maximum *C/I* scheduling, the mobile with the largest received *C/I* is selected at each scheduling point of time. This is possible because at each time slot, the *C/I* values of mobiles are reported to the serving base station as channel qualities. Proportional fair scheduling is widely used in system-level simulators for cellular standards. In proportional fair scheduling, priority values for all the practically dropped mobiles are evaluated and the mobile with the highest priority is selected. The priority value of mobile i at time k, $P_i(k)$, is expressed as a function of the selected data rate of mobile i at time k, $DR_i(k)$, and the average throughput (or fairness throughput) of mobile i up to time k, $T_i(k)$, that is, $P_i(k)=[DR_i(k)/\{T_i(k)\}^a]\times f_i$ where a is a constant and f_i is a boosting factor that is dependent on the kind of service. As can be seen, $P_i(k)$ is proportional to $DR_i(k)$ and inversely proportional to $\{T_i(k)\}^a$. Thus, proportional fair scheduling takes channel quality and fairness into consideration at the same time.

The rate at which data are sent to the selected mobile (which is the ratio of the encoder packet size and the transmission duration, or equivalently, the ratio of the encoder packet size and the number of slots for the packet) is determined and selected on the basis of the following information: The forward channel quality reported by the selected mobile, the size of the packet stored in the (re)transmission buffer of the base station, the remaining transmission power for the data, and the number of available Walsh CDMA codes. Specifically, in system-level simulators, the predicted *C/I* ratio is calculated from the forward channel quality and the remaining transmission power (every time slot). The modulation order and code rate are obtained for each possible combination of the encoder packet size, the number of available Walsh codes, and the number of slots for the packet. For each combination of the encoder packet size, modulation order, and code rate obtained above, the required *C/I* ratio is determined from the link-level simulation result for a given, say, 1% packet error rate (PER). Link-level simulators are implemented at the physical layer and the key results are the PER vs. *C/I* curves for available transmission formats that include the encoder packet sizes, modulation orders, and code rates [4] and [5]. Then, for each encoder packet size, selected is the minimum slot length (or equivalently the maximum data rate) satisfying the relation that the predicted *C/I* ratio is greater than the required *C/I* ratio. Finally, among these encoder packet sizes, selected is the encoder packet size for which the data rate is the maximum.

2.6 Packet Error Prediction by Link-Level Results

The mobile sends the decoding result or acknowledgment (ACK/NAK) signal on the reverse link to the base station after receiving and decoding the encoder packet on the forward link. After some delay (typically set to two slots), the base station receives an ACK, a NAK, or a null signal on the reverse link and judges whether the related forward-link transmission was a success or a failure. This mechanism is the automatic repeat request (ARQ). If only a single channel exists for the aotomatic repeat request (ARQ), the base station cannot determine whether to transmit a new packet until an ACK or a NAK signal is received. To enable consecutive transmission, multiple ARQ channels are introduced. In view of the assumed delay of 3 slots before the reception of the ACK/NAK signal, the base station transmits the encoder packet every four slots. The *4n-th*, *(4n+1)-th*, *(4n+2)-th*, and *(4n+3)-th* slots (n=0, 1, 2, ⋯) are occupied by each of four ARQ channels and therefore distinct packets may be transmitted on each ARQ channel. In forward-link system-level simulators, ARQ channels are modeled as ARQ channel buffers (or retransmission buffers) on the base station side. If the base station receives the ACK signal, it removes the related encoder packet from the corresponding ARQ channel buffer. If the base station receives the NAK signal, it keeps the related encoder packet in the corresponding ARQ channel buffer and expects retransmission. If, however, the number of retransmissions exceeds its limit, the base station removes the related encoder packet from the corresponding ARQ channel buffer.

In the forward-link system-level simulators, the received *C/I* ratio at the mobile is calculated by adding the *C/I* ratio for each path of a given (multipath) channel model between the mobile and the serving sector. Then, the resulting effective *C/I* ratio is obtained in the same manner as the effective pilot E_c/I_o, considering self interference, as explained in subsection 2.4. The effective *C/I* ratio is obtained every time slot and includes the (short-term) fading effect. This effective *C/I* ratio is averaged over the number of slots for each encoder packet. At the end of transmission of each encoder packet, a real uniform random variable is generated between 0 and 1 and compared with the PER corresponding to the effective *C/I* ratio. The relations between PER and *C/I* ratio are obtained from link-level simulations, as mentioned in subsection 2.5. If the generated random variable is less than the PER, a NAK signal is sent by the mobile and if the random variable is greater than the PER, an ACK signal is sent. The system capacity, coverage, or throughput of cdma2000 systems can be obtained through dynamic simulation with simulation time of typically more than a few minutes.

2.7 Traffic Generation and Higher-Layer Modeling

Traffic source models in system-level simulators include HTTP, WAP (wireless application protocol), near real time video, and FTP whose proportions may be set to 30%, 30%, 20%, and 20% [1]. If a full buffer model is assumed instead, traffic always exists and generation of traffic source models is not needed. In case of generation of traffic source models using adequate random variables [1], information including packet sizes and occurrence times is stored in the initial transmission buffer.

HTTP and FTP models are based on the TCP model and entail feedback on transmission completion of each packet. Thus, these models need for per packet monitoring of transmission and at the end point of time of each packet transmission, indication to traffic generation is necessary. This is implemented in the acknowledgment reception part of system-level simulators.

3. Design Examples

In this section, design procedures and considerations of system-level simulators for some example standards are given. System-level simulators for forward-link packet data transmission in cdma2000 [6]-[8] and data transmission in EV-DO BCMCS are considered as design examples.

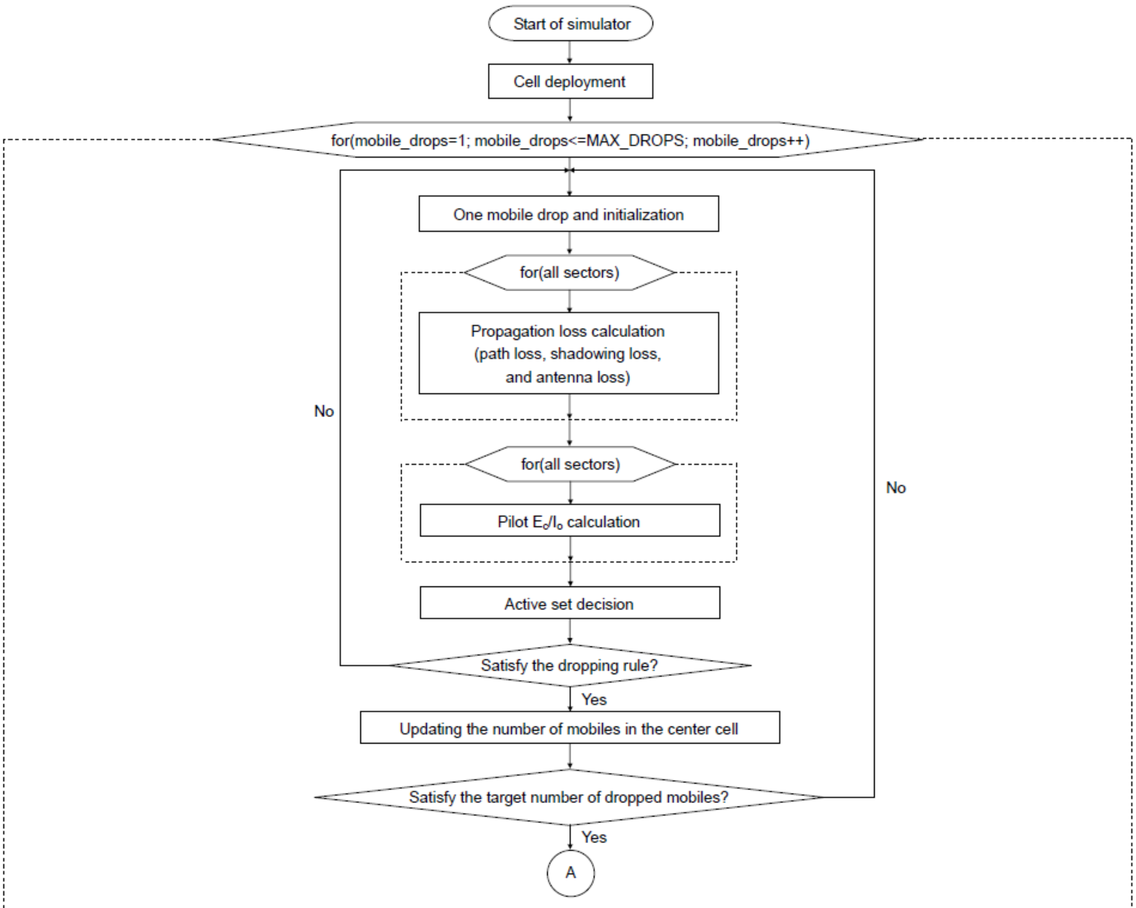
3.1 Forward-Link Packet Data Transmission in cdma2000

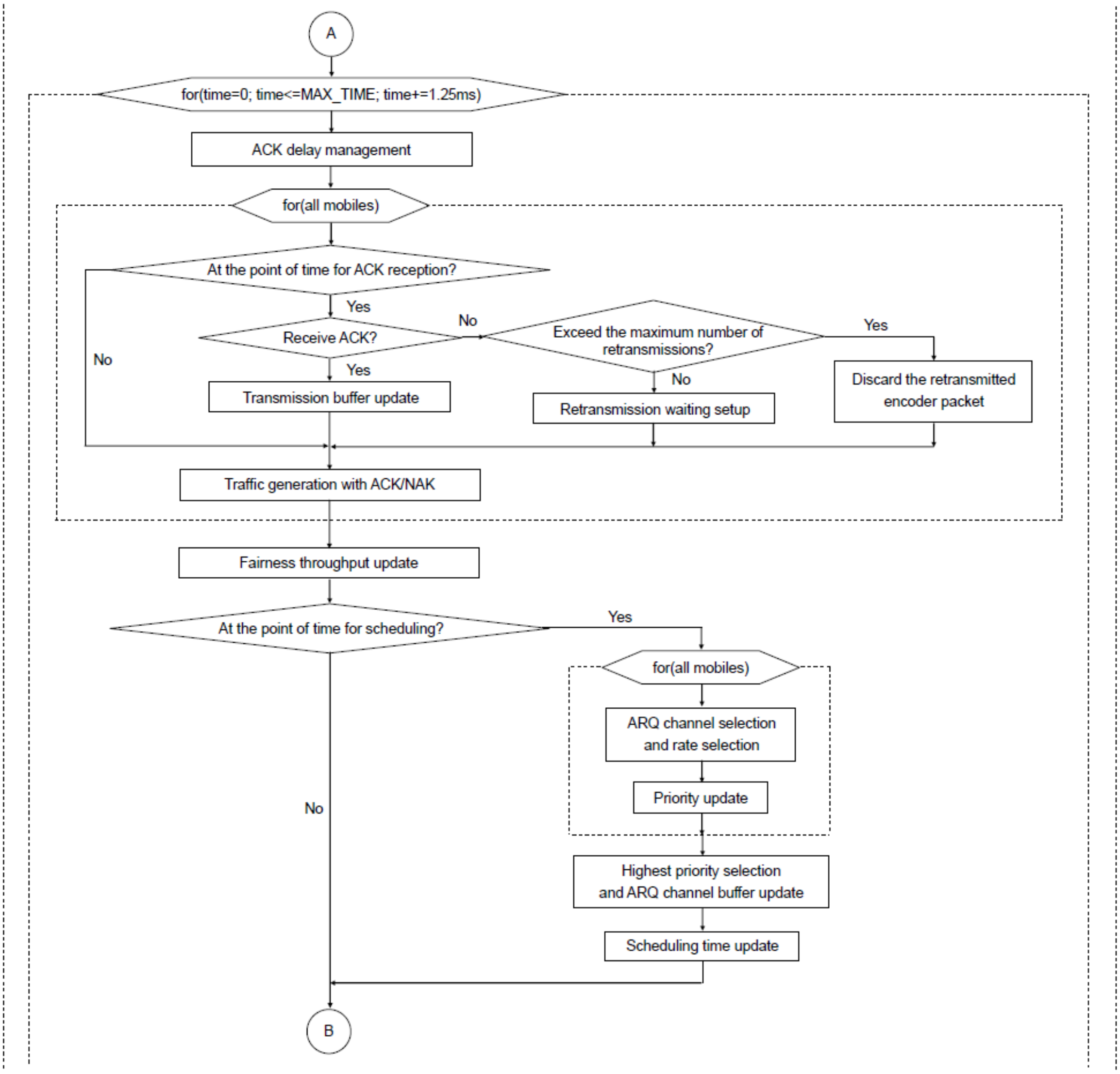
Characteristics and channel operations for the physical layer of the forward-link cdma2000 system are described in [9]. The packet data system-level simulator for the forward link of cdma2000 is developed. According to the procedure and guidelines mentioned in the foregoing sections, the flow chart of the simulator is summarized in Fig. 3. Drop and initialization, base station side operations, and mobile side operations are illustrated, which constitute the overall packet data system-level simulator. Capacity or sector throughput can be obtained from the developed simulator.

3.2 Data Transmission in EV-DO BCMCS

The system-level simulator for EV-DO BCMCS [10] and [11] is developed for coverage simulation. In the simulator, BCMCS data are broadcast on the forward link to mobiles according to transmission mechanisms of EV-DO. The ARQ operation is deactivated on the reverse link and hence decoding at each mobile is performed only at the end time of transmission of each packet. Reed-Solomon (RS) outer code is employed and soft combining of four strongest signal paths at each mobile is assumed for performance improvement. Coverage of 95% means that out of a hundred mobiles, ninety-five mobiles meet the target PER of, say, 1%. Fig. 4 shows some coverage simulation results for the developed BCMCS system-level simulator. In simulations for dual-antenna mobiles, antenna correlation is ignored and accordingly the minimum mean square error combining is equivalent to the maximal ratio combining. Under the target PER of 1% and the pedestrian channel model, data rates of up to 204. kbps and up to 409.6 kbps meet the 95% coverage condition for single- and dual-antenna mobiles, respectively.

Depending on the channel states, the real field tests and also [12] showed that, for the single-antenna mobile and pedestrian channels, coverage values were 100, 100, ≥98, and ≥82 percent for physical data rates of 76.8, 153.6, 204.8, and 307.2 kbps, respectively. For the dual-antenna mobile and pedestrian channels, actual coverage values were 100, 100, 100, ≥92, and ≥60 percent in the worst case for




A
for(time=0; time<=MAX_TIME; time+=1.25ms)
ACK delay management
for(all mobiles)
At the point of time for ACK reception?
Yes
No
Receive ACK?
No
Exceed the maximum number of retransmissions?
Yes
Yes
Transmission buffer update
No
Retransmission waiting setup
Discard the retransmitted encoder packet
Traffic generation with ACK/NAK
Fairness throughput update
At the point of time for scheduling?
Yes
for(all mobiles)
ARQ channel selection and rate selection
Priority update
No
Highest priority selection and ARQ channel buffer update
Scheduling time update
B

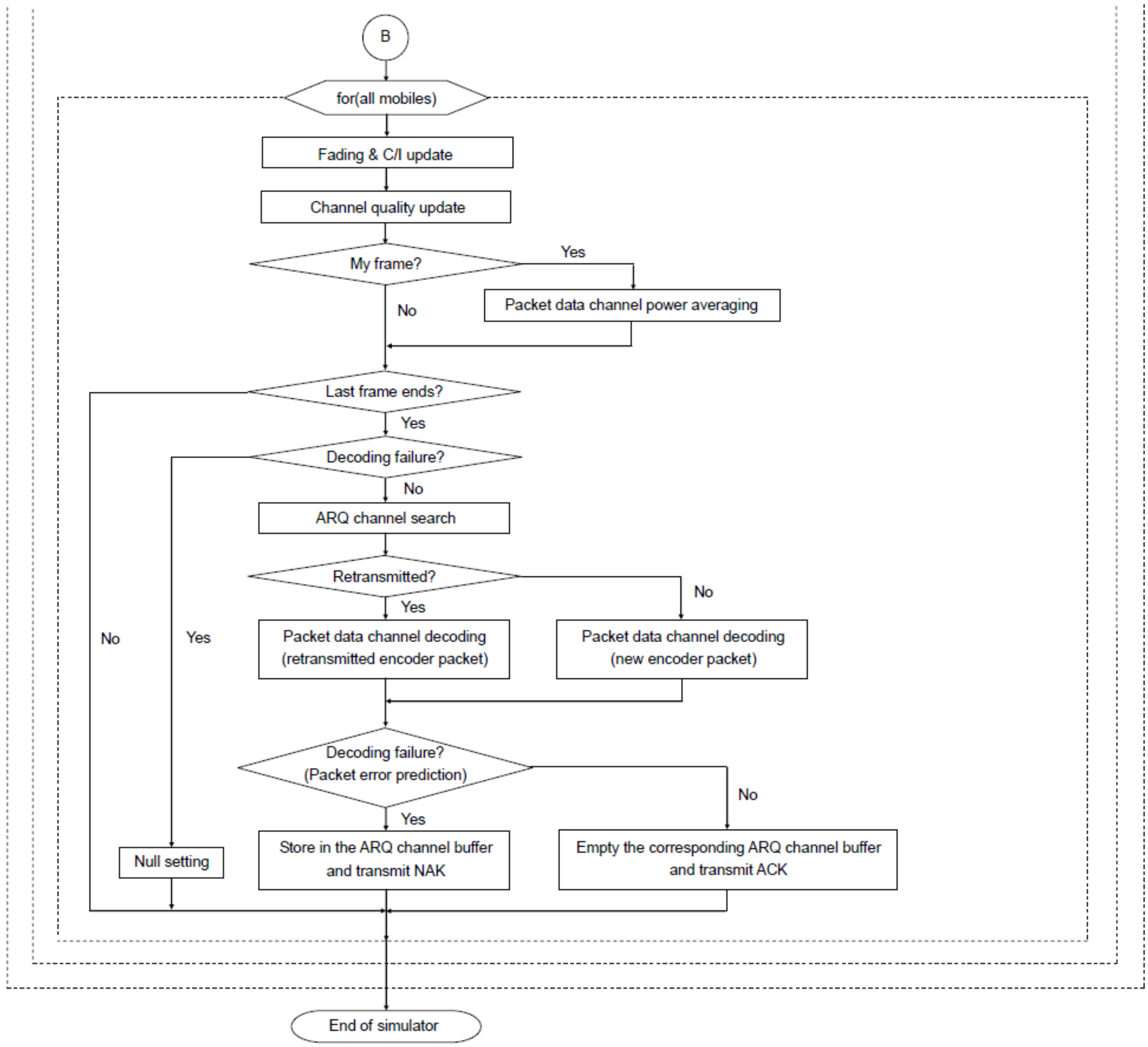


Fig. 3. A simulator flow chart for forward-link packet data transmission in cdma2000
(From the start of simulator node to node A) Drop and initialization
(From node A to node B) Base station side operations
(From node B to the end of simulator node) Mobile side operations

data rates of 153.6, 204.8, 307.2, 409.6, and 614.4 kbps, respectively. Thus, the coverage results acquired from the developed simulator in this paper are in good agreement with the field test results. Non-crucial discrepancy between the simulated coverage and the actual coverage in the high data rate regime is attributed to the non-time-varying model of log-normal shadowing and the application of a more sophisticated RS channel code.

4. Conclusion

Design methodology with design considerations, guidelines, and flow charts for system-level simulators are explained in this tutorial paper. System-level simulators are employed to assess and predict the air link performance with the aid of link-level results, evaluating capacity and coverage. Systematic and well organized design of system-level simulators is

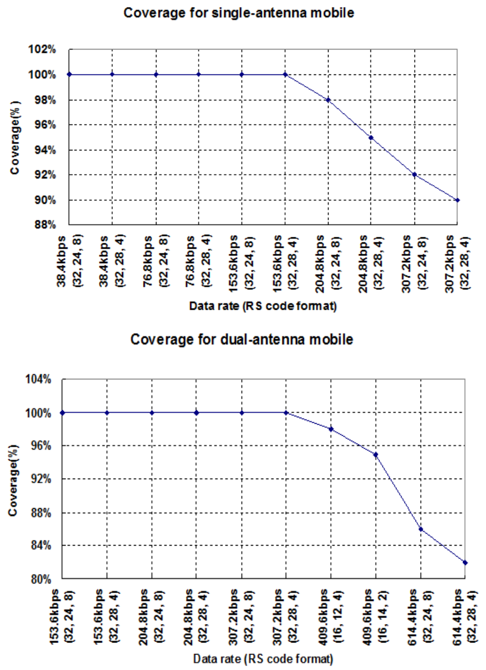


Fig. 4. Coverage simulation results for EV-DO BCMCS

needed for correct performance evaluation of cellular standards, prior to field tests.

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