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THE PERFORMANCE OF BASE STATION INTERCONNECTION ALTERNATIVES IN CDMA NETWORKS*

N. Gerlich

Code Division Multiple Access (CDMA) technology emerges as one of the key technologies for third generation personal communication systems. Although the air link capacity is the scarce resource in a wireless system, it is nevertheless important to design the land interconnecting network efficiently. In this paper we discuss the capacities of architecture alternatives for the interconnection of Base Transceiver Systems (BTS) and their Base Station Controller (BSC) in CDMA mobile communication networks. To this end, queuing models of architecture alternatives are derived. We analyze the models using discrete-time analysis techniques and verify the results by simulation. Numerical results are provided for the maximum number of CDMA voice sources that can be supported by a given capacity of the interconnecting links. This enables us to compare the architecture alternatives in terms of teletraffic capacity.

1 BTS–BSC Interconnection Alternatives

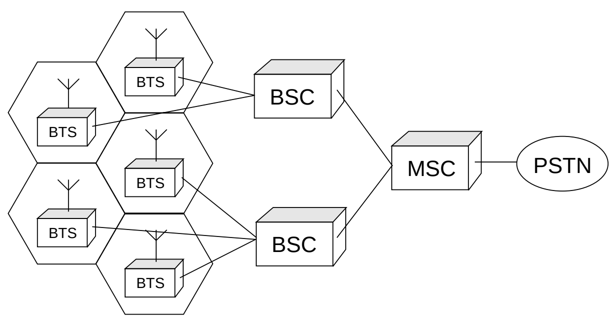

Figure 1: CDMA Cellular Land Network

Code Division Multiple Access (CDMA) will play a major role as the preferred multiple access scheme on the air interface of next generation personal communication networks. This is mainly attributed to CDMA's flexible and efficient use of the air link capacity. But after transmission on the air link the voice packets must be forwarded further towards the Mobile Switching Center (MSC) on the land line interconnecting network (cf. Figure 1). Although the air link capacity is the scarcest resource in the network, it is nevertheless important to design the land interconnecting network efficiently. Each Base Transceiver System (BTS) is controlled by a Base Station Controller (BSC), to which it is connected via a leased line of the land based wireline network. The leasing cost is a not neglectable part of the total network operating cost.

Figure 2 shows three architecture alternatives for BTS–BSC interconnection: the star architecture (a), the drop-and-insert architecture (b), and the concentrator architecture (c). The star architecture dedicates an exclusively used link to each BTS. In the drop-and-insert architecture (Mouly and Pautet 1992), also called multidrop architecture or 'daisy chaining' (Mehrotra 1997), a number of BTSs share a common link to the BSC. The name originates from T1 terminology, where drop-and-insert refers to the multiplexer feature to 'drop' or to 'insert' one or more voice channels at a particular multiplexer located anywhere on a multi-point T1 network. In the concentrator architecture a number of BTSs is connected via dedicated links to a traffic

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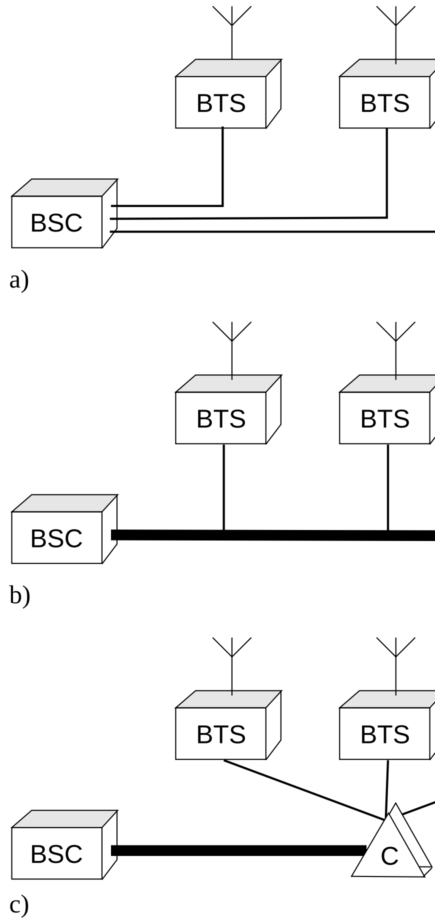

Figure 2: (a) Star, (b) Drop-and-Insert, and (c) Concentrator Architecture

concentrator that in turn is connected to the BSC by another link that is shared by all the BTSs. In a sense, the concentrator architecture combines the other two alternatives. From traffic flow point of view, the links from the BTSs to the concentrator can be treated as the links in the star architecture. Likewise, the link from the concentrator to the BSC can be treated as the link in the drop-and-insert architecture.

The advantage of traffic concentration in the drop-and-insert and the concentrator architecture is analogous to the well known trunking effect (Akimaru and Kawashima 1993). Given a fixed blocking probability, the average carried traffic per line increases with the number of lines in the trunk. The links we are dealing with are different in two aspects. In the BTS–BSC network, voice packets are buffered prior to transmission over unchannelized links; the constraint on the carried traffic is expressed in terms of a delay budget rather than a blocking probability. The *α-delay-budget* defines the upper limit for the α-quantile of the waiting time distribution of an arbitrary packet, i.e., the probability for a packet to wait longer than the delay budget must be less than $1 - \alpha$.

In order to get an estimate of the expected gain, let us employ an M/M/1 delay system. The α-quantile t_α of an M/M/1 delay system can be calculated by (Kleinrock 1975)

$$t_\alpha = \frac{\log \rho - \log(1-\alpha)}{\mu(1-\rho)},$$

where μ is the service rate and $\rho = \lambda/\mu$ is the server utilization under arrival rate λ. Given μ, let λ be the maximum arrival rate such that a given delay budget is maintained. The expected gain can be derived from the answer to the following question: What is the service rate required to serve an arrival stream of rate $i\lambda$ while still keeping the delay budget?

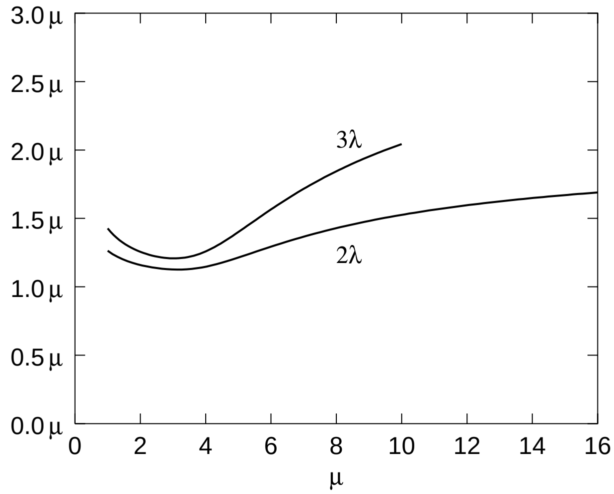

Figure 3: Trunking Gain of M/M/1−∞

Figure 3 shows the required service rate for 2λ and 3λ versus the service rate required for serving λ. The 99.99%-delay-budget is choosen such as to represent 4 ms if $\mu = i$ is intepreted as $i \times 64$ $kbps$. It can be observed that the service rate required to serve $i\lambda$ is considerably smaller than $i\mu$. Judging from this model, the concentrated traffic of three BTSs, demand a 20×64 $kbps$ shared link if each BTS would require a 10×64 $kbps$ dedicated link, thus saving about 30%.

Clearly, modeling the links of the BTS–BSC interconnecting networks by simple $M/M/1$ models is not adequate. But the example gives a rough estimate of the trunking gains that may be expected from the drop-and-insert and concentrator architectures if we assume that three BTSs are sharing one link to the BSC. In this paper we discuss the performance of the BTS–BSC interconnecting alternatives just described. A method is provided for the capacity analysis and dimensioning of the involved communication links to satisfy the Quality of Service (QoS) requirements.

This paper is organized as follows. Section 2 describes in detail the traffic transported in the BTS–BSC interconnecting network. In Section 3, discrete-time queuing models for the different architecture alternatives are derived. These models are analyzed in Section 4. In Section 5, anumerical study is provided; Section 6 concludes the paper.

2 IS-95 CDMA Traffic

Let us first have a look (cf. Figure 1) at IS-95 CDMA (TIA/EIA/IS-95A 1995; Ross and Gilhousen 1996; Ross 1997) voice path from the Mobile Station (MS) to the Mobile Switching Center (MSC). At the MS the vocoder accumulates voice samples and compresses them into a voice packet. The packets are transmitted over the air interface to the Base Transceiver Station (BTS). After retrieval from the raw IS-95 stream, the BTS transmits the packets of all the connections controlled to the Base Station Controller via the BTS–BSC interconnecting network. At the BSC the Selector Bank Subsystem transcodes the packets into Integrated Services Data Network (ISDN) voice packets. The traffic from all BTSs connected to the BSC is forwarded further to the MSC from where it is switched to other MSCs — in case of mobile-to-mobile traffic — or into the Public Switched Telephone Network (PSTN) — in case of mobile-to-land network traffic.

The use of a variable bit rate voice encoder (vocoder) is an important feature of the CDMA technology. Vocoding reduces interference on the radio link and the bandwidth required on the land network. The vocoder detects talk spurts and silence in the voice process and dynamically adapts its transmission rate according to speech activity and noise. In steady state, an 8K vocoder (TIA/EIA/IS-96A 1994) transmits at one of four rates. Depending on the rate, the vocoder generates variable length packets from 160 voice samples accumulated during a 20 *ms* interval. Table 1 lists the packet lengths and state probabilities of the 8K vocoder. The packet lengths shown include 10 octets HDLC header information added at the BTS. Enhanced voice

Rate [*bps*]	Packet Length [*bit*]	Probability
9600	256	0.291
4800	160	0.039
2400	120	0.072
1200	96	0.598

Table 1: Rate Distribution and Corresponding Packet Lengths

quality is provided by the 13K vocoder that operates at a maximum data rate of 14.4 *kbps*. Without loss of generality this paper focuses on the 8K vocoder.

Prior to transmission to the BSC the packets are subjected to the following scheduling by the BTS. One out of 16 time slots within a frame of 20 *ms* is assigned to each voice source during connection setup. The source is only allowed to transmit a packet within its assigned slot. Since the number of connections is usually larger than the number of slots, multiple connections may be assigned to the same slot. The BTS tries to assign the slots such that the load is distributed evenly among the slots. But the free assignment of slots is restricted by soft hand-off requirements.

Calls going through soft hand-off require the same slot in all BTSs to which they are connected. This particular assignment is mandatory in order to ensure that packets originating from the same voice source arrive at the same time at the Selector Bank Subsystem (SBS) of the BSC. Here, digital signal processors decompress the voice packets to retrieve the original voice samples. Due to soft hand-off, more than one packet may be received. In this case the selector chooses the packet promising the best voice quality; the other packets are dropped. In the opposite direction of the connection the packet is copied for each BTS.

Packets waiting for transmission are queued in a common link buffer. The buffer transmits voice and signaling packets in first-in first-out order. Signaling traffic is assumed to generate 1% to 10% of the voice traffic. We concentrate on the voice traffic only and we can scale the obtained results to reflect the effect of signaling traffic.

Due to the buffering the QoS required by the voice traffic is determined by a delay budget and a packet loss ratio. Typically a 99.99%-delay-budget of 4 *ms* and a maximum loss ratio of 10^{-6} must be maintained.

3 Discrete-Time Queuing Models

The literature on statistical multiplexer models is quite extensive (see Hübner 1993). These models usually cope with a buffer whose waiting spaces are capable of holding one packet each; packets have constant length. In contrast, we have to deal with variable length packets to be queued in a buffer, where the elementary storing unit is 1 *bit*.

Thus, we choose to model the link buffer as a finite capacity queuing model operating in discrete time. The buffer accomodates S data-units. The size of a data-unit is given by the greatest common divisor of the packet lengths. Time is discretized into intervals of unit length Δ, which is the transmission time of a single data-unit. Thus, during the slot duration $a \cdot \Delta$, a data-units may be served at maximum by the link. The number of data-units collected during this interval is determined by the number of connections assigned to the slot.

No connections establishing or releasing, this number would be periodic with a period of 16 slots. However, the schedule changes frequently due to termination of connections, hand-off, and the establishment of new connections. Thus, we model the number of connections assigned to a slot by random variable (r.v.) Z.

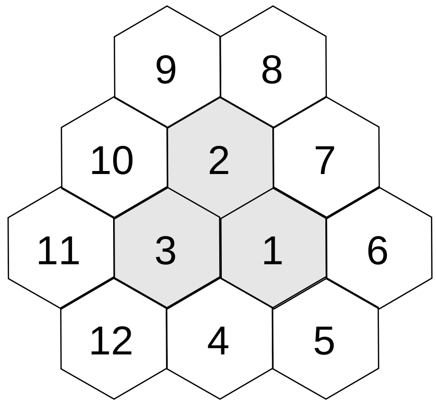

Figure 4: Cluster

For clearity we restrict ourselves in the following to a maximum of three BTSs sharing a link; we will subsume these BTSs to the term *i-chain* with $i = 1, 2, 3$ for ease of notation. The observations naturally extend to higher numbers of BTSs. Furthermore, we assume that only neighboring BTSs are sharing the link — say cells numbers 1,2(,3) of Figure 4 without loss of generality — and that soft hand-off is only possible among contiguous cells. It is also common to restrict the number of BTSs to which a connection may be in soft hand-off to 3. We abbreviate i-way soft hand-off by i-SHO for $i = 1, 2, 3$, where 1-SHO denotes not to be in soft hand-off, i.e. to be connected to one BTS only.

With respect to scheduling the special treatment of soft hand-off connections results in two connection classes: connections without demands (originating connections) and connections demanding a particular slot for transmission (soft hand-off connections). Let Z_0 denote the r.v. number of the former; the latter class must be subdivided further when the link is commonly used by several BTSs like in the drop-and-insert and concentrator architectures. A connection in soft hand-off to several BTSs sharing one link is assigned to the same time slot at all BTSs to which it is connected. Consequently, when multiplexed on the common link this connection delivers more than one packet in the same slot. Thus, we have to deal with three subclasses. Let Z_1 denote the r.v. number of SHO connections which deliver one packet, i.e, connections in 2-SHO or 3-SHO to BTSs not sharing the link. Z_2 denotes the r.v. of SHO connections that transmit two packets. These packets originate from the 2-SHO connections between two BTSs of the chain and from 3-SHO connections to two BTSs of the chain and another BTS not sharing the link. If the latter BTS is also sharing the link, which may be the case only for a 3-chain, these 3-SHO connections deliver three packets. We denote the r.v. number of these connections by Z_3.

Combining all classes gives rise to

$$\begin{aligned} Z &= Z_0 + Z_1 + Z_2 + Z_3; \\ X &= Z_0 + Z_1 + 2Z_2 + 3Z_3, \end{aligned}$$

where we let X denote the number of packets transmitted in a slot.

For the 1-SHO connections we assume that the scheduler performs a perfect load balancing over the 16 slots. Thus, on a basis of N_0 1-SHO connections we get

$$Z_0 = \lfloor N_0/16 \rfloor + \mathsf{BER}(N_0 (\mathrm{mod}\ 16)/16),$$

where $\lfloor x \rfloor$ denotes the largest integer smaller than or equal to x, $\mathsf{BER}(p)$ denotes a r.v. which has a Bernoulli probability mass function (pmf) with parameter p

$$\Pr\{\mathsf{BER}(p) = i\} = \begin{cases} 1-p & i=0 \\ p & i=1 \end{cases},$$

and $x (\mathrm{mod}\ y)$ denotes the remainder of x integer divided by y.

Since 2-SHO and 3-SHO require a particular slot for transmission Z_1, Z_2, and Z_3 are aptly modeled as binomially distributed r.v.

$$Z_i = \mathsf{BIN}(N_i, 1/16), \qquad i = 1, 2, 3,$$

where $\mathsf{BIN}(n,p)$ denotes a r.v. that has a Binomial pmf function with parameters n and p

$$\Pr\{\mathsf{BIN}(n,p) = i\} = \binom{n}{i} p^i (1-p)^{n-i}.$$

To facilitate comparison of the different architectures we derive N_i for $i = 0, 1, 2, 3$ from a basis of N connections per BTS in total and the connection mix of the system. Let $\sigma = (\sigma_1, \sigma_2, \sigma_3)$ denote the connection mix of the system, i.e., σ_i denotes the fraction of connections in i-SHO for $i = 1, 2, 3$.

For the 1-chain, i.e., the link is used exclusively by one BTS, we obviously have

$$\begin{aligned} N_0 &= \sigma_1 N; \\ N_1 &= (\sigma_2 + \sigma_3) N; \\ N_2 &= 0; \\ N_3 &= 0. \end{aligned}$$

The derivation is more complicated with the 2-chain. From combinatoric argumentation we obtain

$$\begin{aligned} N_0 &= \sigma_1 \cdot 2N; \\ N_1 &= (5/6 + 5/6)\sigma_2 N \ + \ (20/30 + 20/30)\sigma_3 N; \\ N_2 &= 1/6\, \sigma_2 N \ + \ (5/30 + 5/30)\sigma_3 N; \\ N_3 &= 0. \end{aligned}$$

For instance N_1 is derived as follows (cf. Figure 4): For each of the cells 1 and 2 there are 5 out of 6 possible candidate cells for 2-SHO with cells not sharing the common link. For 3-SHO there are $5 \cdot 4$ out of $6 \cdot 5$ pairs of cells where both BTSs are not sharing the link. It can easily be verified that $N_0 + N_1 + 2N_2 = 2N$.

For the 3-chain the numbers N_i are derived in a similar manner:

$$\begin{aligned} N_0 &= \sigma_1 \cdot 3N; \\ N_1 &= (4/6 + 4/6 + 4/6)\sigma_2 N \ + \ (12/30 + 12/30 + 12/30)\sigma_3 N; \\ N_2 &= (1/6 + 1/6 + 1/6)\sigma_2 N \ + \ (8/30 + 8/30 + 8/30)\sigma_3 N; \\ N_3 &= 2/30\, \sigma_3 N \end{aligned}$$

Again $N_0 + N_1 + 2N_2 + 3N_3 = 3N$ for verification purposes. It should be noted that N_i, where $i = 0, 1, 2, 3$, must be rounded to integer if necessary.

This model does not cope with the strong positive correlation present in the packet stream of a single vocoder due to talk-spurt/silence alteration (Rose 1997). This problem was addressed by Elsayed (1997) for a link exclusively used by one BTS. The results are very similar to the results reported by Gerlich et al. (1997), where the same link was studied applying a discrete-time queuing model as in the present paper. It is a known fact that positive correlations allow more connections to be multiplexed such that neglecting the correlations leads to conservative estimations of the multiplexing capacity. However, for realistic link speeds, say, faster than $10 \times 64kbps$, a typical buffer of 16 kb can be emptied in less than a frame period of 20 ms. Hence, the buffer 'forgot' about the last packet of a source when the next packet of the same source is arriving. Consequently, the correlation has a small effect if any at all.

4 Analysis

In order to analyze the discrete-time model we extend the discrete-time analysis presented by Gerlich et al. (1997); for the 1-chain the model is essentially the same as studied therein. We first briefly restate this analysis before we aim at extending it for the 2- and 3-chain; for details see Gerlich et al. (1997). Details of the discrete-time analysis technique may be found in Ackroyd (1980, Tran-Gia (1986, Tran-Gia and Ahmadi (1988).

The analysis applies for the partial packet loss policy: If an arriving packet does not fit into the buffer the free positions of the buffer are filled; the remaining data-units are lost. This policy does not make sense from the implementation point of view. But it eases the state analysis of the buffer and leads to approximatly the same results in terms of the packet loss probability and packet waiting time.

The discrete-time analysis bases on the observation of the time-dependent unfinished work process on a slot-by-slot basis. The evolution of this process is described by the recursive equation

$$U_{n+1}^- \quad = \quad \max\{\min\{U_n^- + Y_n,\, S\} - a,\, 0\},$$

where U_n^- denotes the unfinished work just prior to observation instant n, Y_n denotes the number of data-units arriving in the observed slot, S is the buffer size (in data-units), and a is the slot length. In terms of pmfs the last equation reads

$$u_{n+1}^-(k) \quad = \quad \pi_0[\pi^S[u_n^-(k) \circledast y_n(k)] \circledast \delta(k+a)], \tag{1}$$

where $\pi^s[\cdot]$ and $\pi_0[\cdot]$ are linear sweep operators on pmfs defined by

$$\pi^m[p(k)] \quad = \quad \begin{cases} p(k) & \text{for } k < m, \\ \sum_{i=m}^{\infty} p(i) & \text{for } k = m, \\ 0 & \text{for } k > m; \end{cases}$$

$$\pi_m[p(k)] \quad = \quad \begin{cases} 0 & \text{for } k < m, \\ \sum_{i=-\infty}^{m} p(i) & \text{for } k = m, \\ p(k) & \text{for } k > m; \end{cases}$$

and '$\circledast$' denotes the discrete convolution

$$p(k) \quad = \quad p_1(k) \circledast p_2(k) \quad = \quad \sum_{i=-\infty}^{+\infty} p_1(k-i) \cdot p_2(i).$$

Note, that the convolution of a pmf $p(k)$ and the pmf defined by the Kronecker-function

$$\delta(k) \quad = \quad \begin{cases} 1 & \text{for } k = 0, \\ 0 & \text{for } k \neq 0 \end{cases}$$

denotes a shift of $p(k)$ by a indices.

Since Y_n is identically and independently distributed, Eqn. (1) can be iteratively applied in order to determine the equilibrium buffer occupancy pmf

$$u^-(k) \quad = \quad \lim_{n\to\infty} u_n^-(k).$$

The pmf $y_n(k)$ of Y_n is the sum of data-units of X packets and, thus, is given by

$$y_n(k) \quad = \quad \sum_{i=0}^{N} v^{\circledast i}(k) \cdot x(i), \tag{2}$$

where $v^{\circledast i}(k)$ denotes the i-fold convolution of the packet length pmf $v(k)$ with itself and, naturally, $v^{\circledast 0}(k) = \delta(k)$.

In order to calculate the packet loss probability, r.v. Y^* with pmf $y^*(k)$ is defined to be the last data-unit of an arbitrary packet arriving in the batch of packets formed in a slot. The packet is lost if $U^- + Y^* > s$. Thus,

$$p_{\text{loss}} \quad = \quad \sum_{i=S+1}^{\infty} u(i) \circledast y^*(i).$$

The derivation of $y^*(k)$ starts from the conditional pmf $y^*_{|X=j}(k)$, which denotes the pmf of an arbitrary packet's end within a batch of j packets. Since the position of an arbitrary packet within the batch is uniformly distributed, complete probability formula gives rise to

$$y^*_{|X=j}(k) \quad = \quad \frac{1}{j} \cdot \sum_{i=1}^{j} v^{\circledast i}(k). \tag{3}$$

The probability for an arbitrary packet to arrive within a batch of j packets given by $j \cdot x(j)/\mathrm{E}[X]$ unconditioning leads to

$$y^*(k) \quad = \quad \frac{1}{E[\ X\ ]} \sum_{j=1}^{N} x(j) \sum_{i=1}^{j} v^{\circledast i}(k),$$

where $\mathrm{E}[X]$ denotes the expectation of r.v. X.

Again using Y^* the waiting time pmf of an arbitrary packet is

$$w(k) \quad = \quad \begin{cases} \dfrac{u^-(k) \circledast y^*(k)}{\sum_{i=0}^{S} u^-(i) \circledast y^*(i)} & 0 \leq k \leq S, \\ 0 & k > S. \end{cases}$$

In order to extend this analysis to apply to the 2- and 3-chain model, only the pmfs $y_n(k)$ and $y^*(k)$ have to be derived in a different manner. In the derivation of $y_n(k)$ we have to reflect the fact that each of Z_2 connections delivers two packets of identical size and Z_3 connections deliver three packets of equal size. If the packet size of such a connection is V then the number of data-units delivered is $2V$ and $3V$, respectively. The pmf of r.v. $j \cdot V$ can be expressed using the operator $\eta_j[\cdot]$ defined by

$$\eta_j[v(jk)] \quad = \quad v(k).$$

Thus, we get

$$y_n(k) = \sum_{i=0}^{N_0} v^{\circledast i}(k) \cdot z_0(i) + \sum_{j=1}^{3} \sum_{i=0}^{N_j} \eta_j [v(k)]^{\circledast i} \cdot z_j(i). \tag{4}$$

The same problem arises in the derivation of $y^*(k)$. Here we get

$$y^*_{|X=j}(k) = \frac{1}{j} \cdot \sum_{n_0+n_1+n_2+n_3=j} \left(\sum_{i=1}^{n_0+n_1} y_1^*(k) + \sum_{i=1}^{n_2} y_2^*(k) + \sum_{i=1}^{n_3} y_3^*(k) \right), \tag{5}$$

with

$$\begin{aligned}
y_1^*(k) &= v^{\circledast i}(k); \\
y_2^*(k) &= \left[v^{\circledast(n_0+n_1)}(k) \circledast \eta_2[v(k)]^{\circledast(i-1)} \circledast v(k) \right] + \left[v^{\circledast(n_0+n_1)} \circledast \eta_2[v(k)]^{\circledast(i)} \right]; \\
y_3^*(k) &= \left[v^{\circledast(n_0+n_1)}(k) \circledast \eta_2[v(k)]^{\circledast n_2} \circledast \eta_3[v(k)]^{\circledast(i-1)} \circledast v(k) \right] \\
&+ \left[v^{\circledast(n_0+n_1)}(k) \circledast \eta_2[v(k)]^{\circledast n_2} \circledast \eta_3[v(k)]^{\circledast(i-1)} \circledast \eta_2[v(k)] \right] \\
&+ \left[v^{\circledast(n_0+n_1)}(k) \circledast \eta_2[v(k)]^{\circledast n_2} \circledast \eta_3[v(k)]^{\circledast i} \right].
\end{aligned}$$

Replacing Eqns. (2) and (3) by Eqns. (4) and (5) extends the 1-chain analysis to the 2- and 3-chain cases.

5 Results

For the numerical results presented in this section the parameters of the model are set as follows. The packet length distribution is the rate distribution of the 8K vocoder listed in Table 1. The buffer length is 16 *kb*. We assume a connection mix of $\sigma = (50\%, 30\%, 20\%)$. The QoS requirements are given by a 99.99%-delay-budget of 4 *ms* and a maximum packet loss ratio of 10^{-6}.

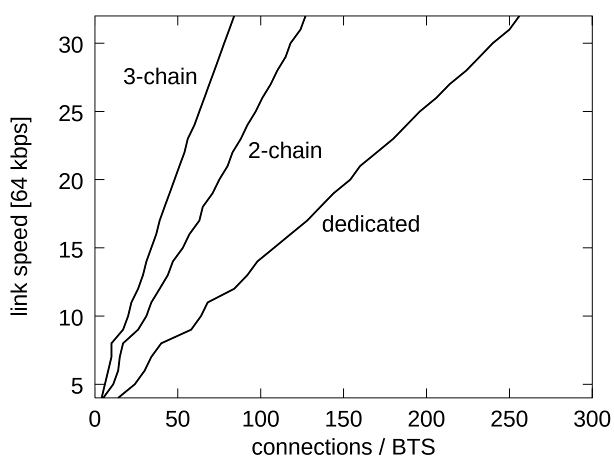

Figure 5: Required Link Speed

Given a number of voice connections per BTS Figure 5 shows the required link speed for the star (dedicated link) and drop-and-insert and concentrator architectures (2- and 3-chains). In all curves we note a linear increase in the required link speed as the number of connections increases

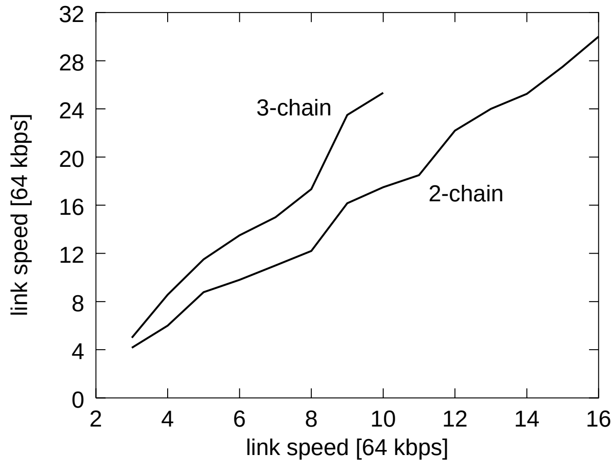

Figure 6: Trunking Gain

linearly. This known behavior of packet multiplexers enables us to apply linear interpolation for calculating the graphs of Figure 6.

Figure 6 shows the link speed that is required for the link shared by 2 and 3 BTSs, respectively, versus the link speed each of the BTSs would require when served by a dedicated link. For a cluster of medium loaded BTSs, say, serving 24 connections each, the star architecture requires links of 5×64 *kbps*, the drop-and-insert and concentrator architectures demand 9×64 *kbps* in a 2-chain and 12×64 *kbps* in a 3-chain. In order to serve the theoretical single carrier maximum of 63 connections per BTS the star architecture requires 10×64 *kbps* per link, the 2-chain 17×64 *kbps*, and the 3-chain 25×64 *kbps*. Thus, the chaining reduces the required link capacity by about 10-20%. Though, as expected, the gain does not reach the savings of the M/M/1 delay system presented in Section 1. The other way round we conclude further, that, given i BTSs connected to a concentrator, the links between BTSs and concentrator must have more than $1/i$ of the capacity of the shared link to earn the gain.

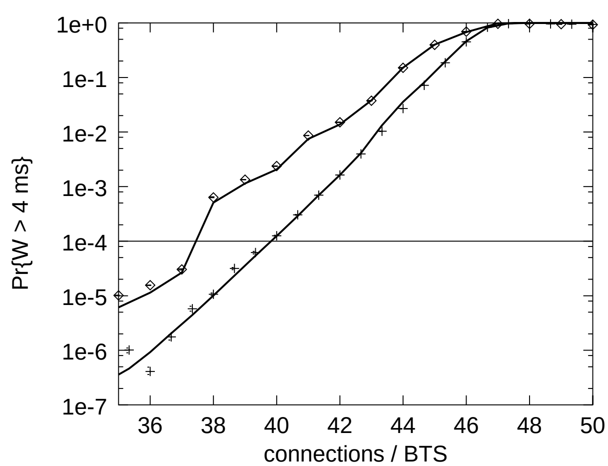

Figure 7: Correlation

Finally, Figure 7 compares the analytical result with results from simulation experiments. The figure shows the probability to exceed the delay budget versus the number of connections per BTS for a dedicated link and a 3-chain of 16×64 *kbps*. Allowing approximation errors in both analysis and simulation, the results match quite well. Figure 7 also illustrates the effect of the correlations among packet sizes in the chains due to soft handover. No such correlations present, the analysis for the dedicated link could have been applied also for the chains. Correlated packet sizes due to soft handoff lead to higher probabilities for exceeding the delay budget than in the uncorrelated case.

6 Conclusion and Outlook

In this paper different architectures for CDMA network BTS–BSC interconnection are compared in terms of teletraffic capacity: the star architecture, the drop-and-insert, and the concentrator architecture. For capacity assessment a discrete-time queuing model is derived that is capable of modeling the interconnection links of the architecture alternatives. The discrete-time analysis of Gerlich et al. (1997) is extended to provide a method for the capacity analysis and dimensioning of the communication links involved. Numerical results show a considerable gain in traffic capacity for the drop-and-insert and concentrator architectures over the star architecture. The gain is larger for slow link speeds. Given i BTSs connected to a traffic concentrator the links between BTSs and concentrator must have more than $1/i$ of the capacity of the shared link to earn the gain.

At the time third generation systems will be mature for implementation, the Asynchronous Transfer Mode (ATM) will be the major broadband transport system in the land network providing cost efficient data transmission. Thus, third generation CDMA networks likely will utilize the ATM infrastructure for BTS–BSC interconnection. The fast ATM links require traffic concentration as provided by the drop-and-insert and concentrator architecture to be cost-efficient. It remains subject for further research to assess the capacity of these architectures based on AAL-2 multiplexing.

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