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CARRYING CDMA TRAFFIC OVER ATM USING AAL–2: A PERFORMANCE STUDY[*]

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In personal communication systems based on Code Division Multiple Access (CDMA), voice is transported as compressed low bit rate information between network elements. Due to cost efficiency, future implementations of CDMA networks likely will utilize the Asynchronous Transfer Mode (ATM) technology to connect components of the land network infrastructure. This paper discusses the capability of using ATM real-time connections in correspondence with the ATM Adaptation Layer 2 to carry compressed voice between CDMA network components. Two different scenarios are considered: the Base Transceiver Station to Base Station Controller connection and the connection between two Base Station Controllers. Capacity and performance evaluations are derived by means of simulation.

1 Introduction

Code Division Multiple Access (CDMA) and Asynchronous Transfer Mode (ATM) are two of the key technologies of next generation communication systems. While CDMA serves for wireless personal communications, ATM will be the major broadband transport system in the land network providing cost efficient data transmissions. Hence, future CDMA networks likely will utilize the existing ATM based infrastructure to connect network components.

The variable bit rate voice encoding implemented in CDMA systems generates low bit rate data streams on voice paths connecting one mobile station to its counterpart. Carrying such traffic on broadband networks requires appropriate adaptation in order to avoid at the same time the waste of capacity and untolerable delays. This paper discusses the capability of using ATM real-time connections in correspondence with the ATM Adaptation Layer 2 (AAL-2) [5] for carrying compressed voice between components of the CDMA land network part.

Due to the flexibility and efficiency of both technologies, the combination of CDMA and ATM has become an issue in the recent time. A CDMA network architecture equipped with network elements based on ATM switches was proposed in [10]. Advantages claimed are easy handling of handoff functions and straightforward adoption of the voice detection function inherent in CDMA by ATM equipment. A CDMA architecture where ATM is used not only for the interconnection of the land network part but also over the air interface is discussed in [6]. It is argued that the approach leads to a highly flexible interface between mobile connections and the ATM-based broadband network.

In the approach presented in this paper, ATM technology is suggested to interconnect CDMA network components instead of using conventional T1/E1 links in order to increase cost efficiency. Therefore, each component of the CDMA land network part only has to be modified slightly besides from adding interfaces to connect with ATM links. Quality of Service (QoS) objectives which determine the type of ATM connection are: to keep a delay budget requested by the CDMA system, not to exceed a certain loss ratio for voice packets, and to efficiently use the capacity reserved in the ATM network. The CDMA network connections under consideration are the links between the Base Transceiver Station (BTS) and its Base Station Controller (BSC),

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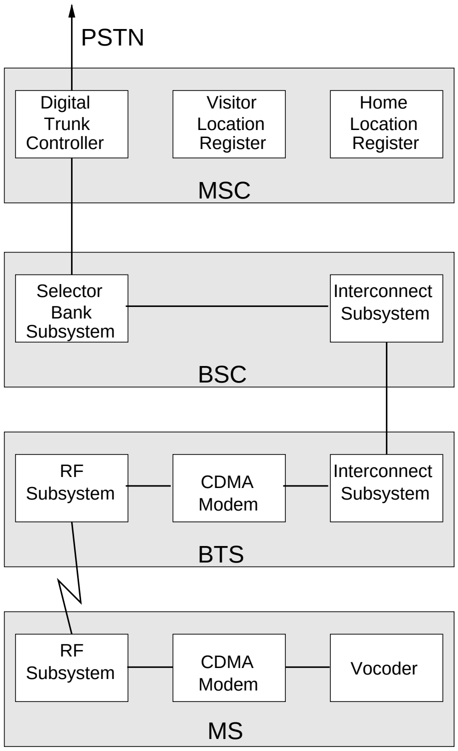

Figure 1: Outline of the IS-95 CDMA architecture

and between two BSCs. Appropriate traffic models are derived for capacity estimations and performance evaluations by means of simulation.

The paper is organized as follows. In Section 2 the IS-95 CDMA network architecture is introduced. Section 3 describes the transport of low bit rate compressed voice over ATM and Section 4 presents the simulation models and states the objectives. A numerical study of performance parameters is provided in Section 5. The paper concludes with final remarks in Section 6.

2 IS-95 CDMA Network Architecture

A typical IS-95 CDMA [8, 7] architecture is depicted in Figure 1, showing the 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). The packets of all connections controlled by the BTS are transmitted to the Base Station Controller (BSC) via an unchannelized T1/E1 link. At the BSC the packets are forwarded to the Selector Bank Subsystem, where the voice packets are transcoded into Integrated Services Data Network (ISDN) voice traffic. The traffic from all BTSs connected to the BSC is routed to the MSC via another T1/E1 link 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. For mobile-to-mobile connections, the packets traverse the voice path in opposite direction at the peer site.

The use of a variable bit rate voice encoder is an important feature of the CDMA technology. Vocoding reduces interference on the radio link and the required bandwidth on the land network. The vocoder detects talk spurts and silence in the voice process and dynamically adapts its data rate according to speech activity and noise. In steady state, an 8K vocoder (see [8], Appendix

A) transmits at one of four rates. Depending on the rate the vocoder generates variable length packets out of 160 voice samples accumulated during a 20 *ms* interval. Table 1 lists the packet lengths and rate probabilities of the 8K vocoder. The packet lengths shown include 10 octets header information added at the BTS. An enhanced voice 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.

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

At the BTS, voice packets are retrieved from the raw IS-95 stream and scheduled for transmission to the BSC. To this end 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 assigns the slots such that the load is distributed evenly among the slots. Though, the free assignment of slots to connections is restricted by the fact that calls going through soft handoff require the same slot in all BTSs to which they are connected.

This particular assignment is required 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. If there is more than one packet due to soft handoff 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. Finally, the voice samples are transcoded into ISDN voice traffic and transmitted to the MSC. The MSC is typically an ISDN switch with some Intelligent Network (IN) functionality added. For example, user profiles and location information is held in the Home Location Register (HLR) and Visitor Location Register (VLR) databases.

When focusing on the land network connections of this architecture, the following links are distinguished: the BTS–BSC connection, the BSC–MSC connection, and the MSC–MSC connection. CDMA characteristic traffic is found only on the BTS–BSC link since the traffic is transcoded into ISDN traffic at the BSC. For mobile-to-land network calls this is necessary since neither the MSC nor the terminal equipment has a built-in vocoder. Consequently, for mobile-to-mobile traffic the packetized voice is transcoded into ISDN signals, transported through the network, and transcoded back into vocoder packetized voice at the peer BSC. In fact, the receiving BSC may be the same as the originating BSC if both mobiles are controlled by the same station. The reason why also mobile-to-mobile traffic is transcoded into ISDN traffic is to keep the switching capability of the MSC strictly similar to that of an ISDN switch.

In the presence of a broadband ATM network infrastructure the situation changes. With ATM, the motivation for transcoding mobile-to-mobile calls to ISDN traffic ceases to apply. Consequently, apart from the connection scenario discussed above the logical link between two BSCs can be established using an ATM connection. The resulting interconnection architecture is illustrated in Figure 2. With respect to the network elements, the current system architecture is kept with only minor changes to adopt for the new interconnection structure. Apart from implementing an ATM interface card the BTS remains unchanged. The traffic on the BTS–BTS link thus exhibits the traffic characteristics given by the vocoder behavior and the framing structure

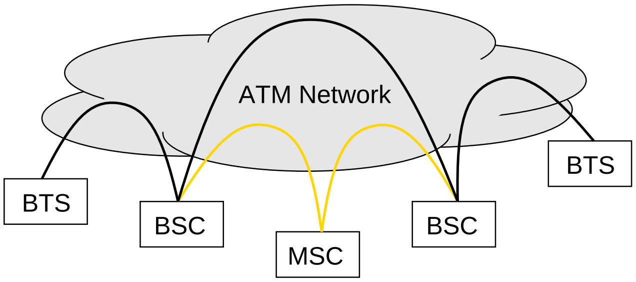

Figure 2: Interconnecting CDMA network elements using ATM

of the transmission scheduler (see above). The scheduling procedure has to be maintained due to the handling of soft handoff calls at the BSC and its internal structure and operation mode.

Mobile-to-land calls are treated by the BSC as before. The only change to the BSC in addition to adding an ATM link interface card is the treatment of mobile-to-mobile calls. Packets of such calls are not transcoded after selection at the SBS but routed to the peer BSC. Three options are available:

- Establishing a direct BSC–BSC connection:
  This is a reasonable choice only if the traffic volume between a pair of BSCs is large enough. In the worst case, however, there may be a single connection only, that is, a single 9.6 *kbps* connection which cannot be transported efficiently over an ATM link given the tight delay budgets of compressed voice traffic.

- Routing the traffic via the MSC but separated from mobile-to-land calls.
  For this option, two connections have to be established between BSC and MSC: one for mobile-to-land calls showing ISDN traffic characteristics, and another for mobile-to-mobile calls showing vocoder traffic characteristics.

- Carrying both mobile-to-mobile and mobile-to-land calls on a single BSC–MSC connection:
  The connection then must be capable of carrying a number of isochronous Constant Bit Rate (CBR) connections together with a number of Variable Bit Rate (VBR) connections.

The first two options seem to be more feasible. Both options are equivalent from modeling point of view in such that the traffic offered to the link carrying the mobile-to-mobile calls differs in volume only but not in its characteristics. Thus, the paper concentrates on the BTS–BSC connection and the BSC–BSC connection established over ATM network links.

3 Compressed Voice Over ATM

Although data traffic has been growing steadily over the past few years, voice continues to be an important requirement for ATM enterprise networks. ATM provides the opportunity of decreasing significantly the cost of voice communications, allows a great flexibility in resource allocation, and simplifies the operational environment. More important, ATM will revolutionize the industry with fundamental changes to the cost/value equation due to better bandwidth effectiveness.

When talking about voice networking over ATM in the WAN, two alternatives must be differentiated. First, each call may be routed and transported individually over switched virtual connections, which is an appropriate solution for mobile-to-land traffic. This type of calls is most efficiently transported as real-time VBR virtual connection, with voice quality assured via sophisticated voice adaptation techniques and quality of service support [9]. Second, ATM networks may be used for tunneling vocoder traffic, typically multiplexing a number of calls together. In the CDMA architecture, this applies for connections linking the network elements BTS-BSC and BSC-BSC together, which are established in today's mobile networks utilizing unchannelized T1/E1 links.

To support those connections in ATM networks economically, an appropriate means of transportation is required, which provides a bandwidth efficient transmission of low-rate, short and variable length packets for delay sensitive applications [2]. Accumulating voice probes to fill the payload of ATM cells completely would result in delays which can not be tolerated, whereas the transmission of such probes in one ATM cell each leads to an inefficient transportation. The ATM Adaptation Layer (AAL) Type 2 specified by the ITU-T Recommendation I.363.2 [5] was designed for this purpose. It makes use of the ATM layer service and is capable of transfering service data units from one end system to another end system through an ATM network. The underlying ATM layer service may be CBR or real-time VBR. In the following we briefly describe the frame structure of the short variable length packets, the packing of these packets into ATM cells, and the mechanisms to recover from transmission errors, specified for AAL type 2.

A packet on the Common Part Sublayer (CPS) of AAL type 2 consists of a 3-byte CPS-Packet header followed by a CPS-Packet payload. The size and positions of the fields are shown in Figure 3. The channel identifier (CID) indicates the AAL type 2 user of the connection. It is required since more than one user information stream can be supported on a single ATM connection. The number of bytes in the CPS-Packet payload are encoded in the length indicator (LI). By default, the maximum length is set to 45 bytes. Otherwise, the maximum can be set to 64. The user-to-user indication (UUI) field serves two purposes: to convey specific information transparently between the users and to distinguish between service specific entities and layer management users. Finally, a header error control (HEC) is added.

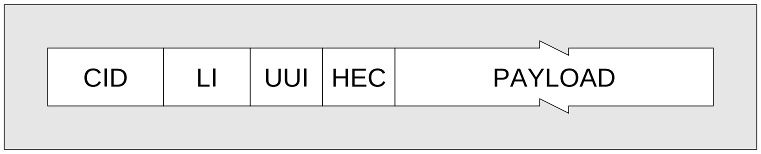

Figure 3: Format of AAL type 2 CPS-Packets

In order to pack CPS-Packets into protocol data units (CPS-PDU) which are passed on to the ATM layer, a one byte start field is added to each 47 bytes of payload, cf. Figure 4. The start field consists of an offset field (OSF), a sequence number (SN), and a parity bit (P), and is used for error recovery including cell loss. The payload may carry zero, one or more CPS-Packets, that can be contained completely or partially. Unused payload is filled with padding bytes coded with the value zero.

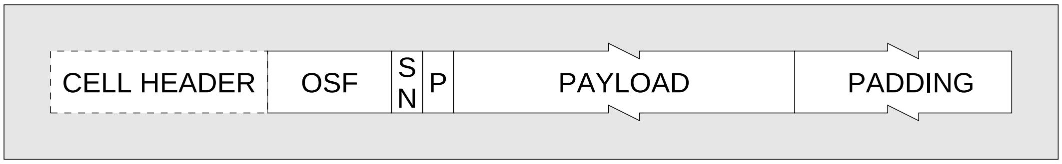

Figure 4: Format of AAL type 2 CPS-PDU

Part of the payload can be left unused since a timer function is implemented to assure that CPS-PDUs with one or more bytes of CPS-Packets already packed wait at most a fixed duration — named TimerCU — before being scheduled for transmission. This mechanism was added to guarantee short delays for very low-rate connections.

Using this packetization technique, variable bit rate voice probes generated by vocoders employed in CDMA systems can efficiently be shared out for transport in the payload of ATM cells. The bandwidth which has to be allocated for those connections is a function of the traffic volume generated by the mobile stations, the characteristics of the traffic, and the setting of the timer function. To assess the bandwidth requirements, an appropriate model of the system environment is introduced in the next section. Using simulation, key questions can be answered and dimensioning guidelines can be given.

4 Simulation Models

In the following we consider separate traffic models for the BTS–BSC and BSC–BSC connection due to significant differences in the characteristics of the offered traffic. To cope with the specific arrival patterns, voice traffic is modeled by appropriate arrival processes. Signaling traffic is regarded negligible since its volume is usually found to be below five percent of the composite traffic volume.

4.1 BTS–BSC Connection

The arrival process of packets for AAL–2 packaging is the same as described in [4] for the capacity analysis of a T1/E1 link connecting BTS and BSC. The random variable packet length is governed by the distribution listed in Table 1. A fixed number N of traffic sources is assumed to be controlled by the BTS. The transmission scheduling is modeled by a random variable fraction of X sources, each transmitting one packet within a slot of 16/20 *msec*. The random variable X follows the binomial distribution $X \sim \mathrm{Bin}(N, 1/16)$.

This covers a worst case scenario due to the following reasoning: Actually, the assignment of sources to slots aims at distributing the connections evenly among the slots. Yet calls undergoing soft handoff require the same slot at all BTSs they are connected to. From a particular BTS's point of view these calls pick one of the 16 slots at random. If a considerable fraction of the N sources is in soft handoff mode, X is approximately binomially distributed.

Consequently, the model does not capture correlation in the arrival process occurring due to the vocoder transmitting the same type of packet during a sequence of frames — for example, full size packets during a talk spurt. This problem is studied in [3] for a T1/E1 link where similar results are reported for a model capturing correlation and a regenerative model. Hence, the results derived with the model described above can be regarded as sufficiently accurate.

The traffic generated such is fed into AAL–2 packetization. The resulting average rate of ATM cells can be calculated as follows. Let $V \sim v(k)$ denote the packet length in units of *octets*. Adding 3 *octets* CPS-Packet Header is expressed by shifting the distribution $v(k)$ by 3 units:

$$v_H(k) \;=\; v(k) \circledast \delta(k-3) \;=\; \sum_{i=-\infty}^{\infty} v(k-i) \cdot \delta(i-3), \tag{1}$$

where the operator '$\circledast$' denotes the discrete convolution and $\delta(\cdot)$ the distribution defined by the Kronecker function

$$\delta(k) \;=\; \begin{cases} 1 & \text{for } k = 0, \\ 0 & \text{for } k \neq 0. \end{cases} \tag{2}$$

Since $X \sim \mathrm{Bin}(N, 1/16)$ packets arrive during each slot, the random variable $Y \sim y(k)$, which

Symbol	Parameter
N	number of sources
t	AAL-2 timeout timer TimerCU
PCR	peak cell rate
SCR	sustainable cell rate
BT	burst tolerance

Table 2: Parameters of BTS–BSC connection model

describes the number of octets arriving, is given by:

$$y(k) \ = \ \sum_{i=0}^{N} v_H^{\circledast i}(k) \cdot \binom{N}{i} \left(\frac{1}{16}\right)^{i} \left(\frac{15}{16}\right)^{N-i}, \tag{3}$$

where $v_H^{\circledast i}(k)$ denotes the i-fold convolution of $v_H(k)$ with itself and, naturally, $v_H^{\circledast 0}(k) = \delta(0)$. Thus, the number of ATM cells $C \sim c(k)$ is governed by

$$c(k) = \sum_{i=47(k-1)}^{47k} y(i) \quad k = 1, 2, \dots\ , \tag{4}$$

due to the payload size of AAL-2 CPS-SDUs which equals 47 *octets*. The average cell rate is calculated by

$$E[C] \ = \ \sum_{i=1}^{\infty} i \cdot c(i) \tag{5}$$

in units of *cells/slot*.

The resulting stream of ATM cells can be transmitted either by utilizing the CBR or VBR service category [1]. If CBR is chosen, the stream has to be shaped according to the Peak Cell Rate (PCR) negotiated in the traffic contract. Depending on the amount of bandwidth reserved, additional delay is introduced. Delays can be avoided when using the VBR service category. However, appropriate values for the Sustainable Cell Rate (SCR) and Burst Tolerance (BT) have to be declared. The dimensioning of these parameters is determined by the Generic Cell Rate Algorithm (GCRA). The parameters of the BTS–BSC traffic model are summarized in Table 2.

4.2 BSC–BSC Connection

The packet arrival process at the BSC–BSC connection is determined by the call mix, the number of calls per BTS, the number of BTSs connected to the BSC, the traffic share of mobile-to-mobile calls, and the internal processing at the BSC. The call mix considered in this paper consists of 50 percent 1-way soft handoff (SHO) calls, 30 percent 2-way SHO calls, and 20 percent 3-way SHO calls. Thus, on the basis of 40 1-way SHO calls/BTS, additional 18 2-way SHO and 12 3-way SHO calls/BTS have to be considered.

Assuming 100 BTSs connected to the BSC and 1 percent mobile-to-mobile traffic, 40 packets/20*msec* are originating from 1-way SHO calls, $18/2 = 9$ packets/20*msec* from 2-way SHO calls, and $12/3 = 4$ packets/20*msec* from 3-way SHO calls. Note that the selector at the BSC chooses only one packet of SHO calls for forwarding to the peer BSC. Hence, a total of 53 packets/20*msec* are required to be transmitted to the peer BSC. The resulting average cell rate can be calculated by Eqn. (5).

Symbol	Parameter
E	inter-arrival time mean
c	inter-arrival time coefficient of variation
t	AAL-2 timeout timer TimerCU
PCR	peak cell rate
SCR	sustainable cell rate
BT	burst tolerance

Table 3: Parameters of BSC–BSC connection model

	N							
	18		36		54		72	
t	d	ρ	d	ρ	d	ρ	d	ρ
1.25	–	.8993	–	.9878	–	.9987	–	.9999
2.50	–	.9567	–	.9982	–	.9999	–	1.000
3.75	–	.9825	–	.9997	–	1.000	–	–
5.00	.004166	.9932	.000060	1.000	–	–	–	–
6.25	.007119	.9974	.000082	–	–	–	–	–
7.50	.008190	.9990	.000092	–	–	–	–	–
8.75	.008488	.9997	.000087	–	–	–	–	–
10.0	.008743	.9999	.000107	–	–	–	–	–

Table 4: Dimensioning of TimerCU for the BTS–BSC connection

The internal processing of packets leads to arrivals of single packets at the BSC–BSC connection. Since apart from the average cell rate no further characteristics of the packet arrival stream are available, a hypothetical type of inter-arrival time distribution must be chosen. In order to study different variabilities of the arrival process, a negative-binomial distribution is used in the following. It allows to set the coefficient of variation almost independent of the mean value.

As in the case of BTS–BSC connections, either the CBR or VBR service category can be used for transmission at the ATM layer. The dimensioning of the corresponding parameters is addressed in the next section. Traffic parameters related to the BSC–BSC model are summarized in Table 3.

5 Results

For the simulation studies presented in this section the following system scenario is considered. The land network elements of the CDMA network are connected by 34 *Mbps* ATM links, that is, the maximum amount of bandwidth accessible on both the BTS–BSC and BSC–BSC connection is limited by this bandwidth. The quality of service provided to the mobile traffic is determined by a delay budget and a packet loss ratio. Looking at the system scenario we consider, the 10^{-4} delay budget should be limited to 4 *msec* — that is, the probability to exceed a delay of 4 *msec* is less than 10^{-4} — and the loss ratio should be smaller than 10^{-6}.

For dimensioning the value of TimerCU in the case of the BTS–BSC connection, the probability d to exceed the delay budget and the utilization ρ of the ATM cell payload are shown in Table 4 as functions of the timer interval t for different numbers of sources N. Generally, the value of TimerCU has to be set smaller than 4 *msec* in order to keep the delay budget. Never-

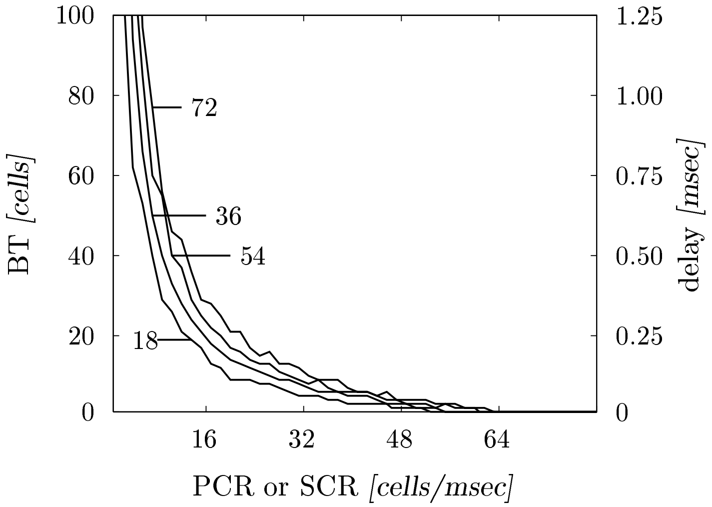

Figure 5: Source traffic descriptor dimensioning for the BTS–BSC connection

theless, larger values can be used to increase the utilization of the ATM cell payload. Table 4 shows that the utilization is already close to 1.0 if the timer is set to 4 *msec*. Even for smaller values of TimerCU, which allow for additional delays due to traffic shaping at the ATM layer, the utilization of the ATM cell payload is high. Increasing the timer interval leads to minor gains in utilization at the cost of missing the constraints given by the delay budget. The effect becomes less distinctive for larger numbers of mobile traffic sources.

The dimensioning of source traffic descriptors for the ATM connection linking BTS to BSC is addressed in Figure 5. As mentioned above, either a CBR or a VBR connection can be established. Figure 5 shows the 10^{-6} delay quantiles for a CBR connection and the 10^{-6} quantiles — regarding the dimensioning of the BT — to observe non-conforming cells for a VBR connection as functions of the PCR and SCR, respectively. The value of TimerCU is set to 3.75 *msec* for each of the curves, which represent traffic scenarios with $N = 18$, 36, 54, and 72 mobile traffic sources. Figure 5 shows that when utilizing a CBR connection in correspondence with traffic shaping, the PCR can be dimensioned close to the average cell rate of the mobile traffic after packetization when a delay budget of 1 *msec* is allowed for shaping. The average cell rates are 0.71, 1.20, 1.63, and 2.04 *cells/msec*, respectively. In order to allow for an additional delay budget of 1 *msec* for traffic shaping, the TimerCU can be reduced by this amount without affecting the utilization of the ATM cell payload considerably. Hence, BTS–BSC mobile traffic can be transported efficiently by the CBR service category when applying AAL–2 packetization. For a VBR connection, a relatively small BT can be declared even when the SCR is chosen close to the average cell rate.

The AAL–2 packetization delay introduced on the BSC–BSC connection is studied with the results given in Table 5. For packet arrival processes having coefficients of variation c ranging from 0.5 to 2.0, similar results as for the BTS–BSC connection can be observed. The utilization of the ATM cell payload is already sufficiently high if the value of TimerCU is set to 4 *msec*. Increasing the value only leads to minor gains in utilization. The dimensioning of source traffic descriptors for the BSC–BSC connection — either CBR or VBR — is addressed in Figure 6. Again, the corresponding 10^{-6} quantiles are shown as functions of the cell rate setting the TimerCU value in order to meet a delay budget constrained by 4 *msec*. Regarding the variability of the arrival traffic, a coefficient of variation close to 1.0 can be expected in real systems, since the composite CDMA packet stream between two BSCs originates from sources which generate traffic independently of each other. In this case, similar conclusions can be drawn as for the BTS–

	c			
	.5	1.0	1.5	2.0
t	d / ρ	d / ρ	d / ρ	d / ρ
0	– / .4657	– / .4726	– / .5035	– / .5513
1	– / .9289	– / .8899	– / .8766	– / .8786
2	– / .9993	– / .9856	– / .9635	– / .9495
3	– / 1.000	– / .9984	– / .9893	– / .9774
4	– / –	– / .9999	– / .9968	– / .9897
5	– / –	.000329 / 1.000	.005622 / .9991	.016631 / .9951
6	– / –	.000332 / –	.005833 / .9997	.017188 / .9977
7	– / –	.000350 / –	.006066 / .9999	.017653 / .9989
8	– / –	.000387 / –	.006216 / 1.000	.017295 / .9994
9	– / –	.000358 / –	.006118 / –	.017603 / .9997
10	– / –	.000374 / –	.005903 / –	.017500 / .9999

Table 5: Dimensioning of TimerCU for the BSC–BSC connection

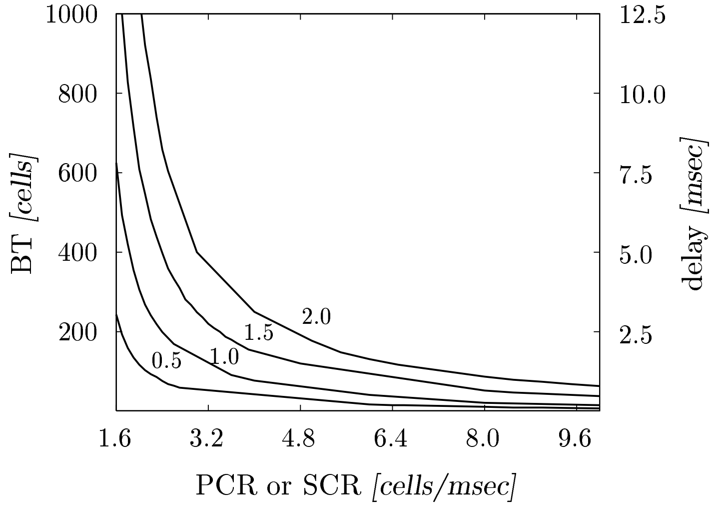

Figure 6: Source traffic descriptor dimensioning for the BSC–BSC connection

BSC connection. For a CBR connection, short delays are introduced due to traffic shaping even when booking a PCR close to the average cell rate, which is 1.61 *cells/msec* for the parameter scenario considered. To meet a certain delay budget, the value of TimerCU can be reduced accordingly without decreasing the utilization of the ATM cell payload considerably. For a VBR connection, again a relatively small BT can be declared for a SCR close to the average cell rate of the mobile traffic carried on the BSC–BSC link.

6 Conclusion and Outlook

In this paper, the efficiency of AAL–2 packetization is studied for transporting CDMA mobile traffic on the BTS–BSC and BSC–BSC link, respectively. Using simulation, delay characteristics observed with AAL–2 packetization and ATM transportation via the CBR and VBR service category are studied. Furthermore, the dimensioning of source traffic descriptors is addressed. Numerical results show that on both the BTS–BSC and BSC–BSC link a timer value set equal to the delay constraints is sufficient to obtain an ATM cell payload utilization close to 1. Larger values lead to a minor increase in utilization.

Regarding the dimensioning of source traffic descriptors, the following conclusions can be drawn. In the case of a CBR connection, only short delays are introduced due to traffic shaping at the ATM layer even when the PCR is set close to the average cell rate of the mobile traffic to be carried. These additional delays are acceptable when setting the AAL–2 timer value smaller than the delay constraint, which does not affect the payload utilization of ATM cells considerably. For a VBR connection, the BT can be kept small for a SCR close to the average cell rate while avoiding cell losses due to non-conforming ATM cells.

All in all, the usage of AAL–2 packetization is an appropriate solution for transporting compressed voice traffic between CDMA land network elements. Delays can be kept small while the utilization of the ATM cell payload is high and the transmission capacity can be reserved close to the average rate of mobile traffic. An issue of future research is the implementation of AAL–2 switching in ATM network nodes, which can play an important role in case of low traffic volumes.

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