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Dynamic Channel Assignment for Picocellular W-ATM Systems

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Abstract — **During the last few years extensive research has been carried out to extend fixed ATM networks to the mobile user. Channel allocation is an important item for mobile communication system. In case of a WATM system two different aspects have to be combined: on the one side the ATM like statistical multiplexing leads to a very dynamic assignment of capacity – on the other side dynamic channel allocation requires a steady behaviour. Due to these opposing requirements, a new allocation scheme is required which has been introduced in [3]. This paper focuses on the influence on capacity allocation and the transmission delay over the air interface.**

I. Introduction

After the success of the *asynchronous transfer mode* (ATM) in the area of multimedia networks during the last years, a lot of research has been carried out to integrate wireless ATM terminals into the ATM network [4, 5, 6]. Currently many international projects are building demonstrators, which will be finished during the next years [7, 8].

To fulfill the requirements of the mobile users, the ATM like statistical multiplexing has to be extended to the air interface (cf. figure 1). This can be done by using a TDMA scheme to divide the physical channel into slots which are able to carry one or several ATM cells. The base station (BS) as a central instance co-ordinates the access of the wireless terminals (WTs) to the common physical channel. It has to share the available channel capacity fairly between the WTs according to the negotiated *Quality of Service* (QoS) parameters and its capacity requests.

The BS assigns these slots to the WTs on a slot to slot basis and informs the WTs by transmitting reservation messages in a special signalling burst. The assigned slots build together with the signalling burst the so called signalling period. Its length is variable and varies over the time. The principle of the resulting signalling scheme in case of time division duplexing (TDD) is shown in figure 2. Further details can be found in [1].

This kind of signalling scheme is used by different Medium Access Control (MAC) protocols such as DSA++[1]/MASCARA[2] and is currently discussed at ETSI BRAN to be standardised as the signalling scheme for future WATM systems.

The statistical multiplexing which is performed via the air interface leads to a very dynamical assignment of capacity to the terminals. Since the capacity assignment changes from period to period, there is no prediction of future assignments possible.

On the other side, dynamic channel allocation schemes measure the current channel situation and perform on these measurements a prediction of the future situation. Therefore, dynamic channel allocation schemes are only able to work effectively, if there is a certain steadiness in the allocated channels.

On the one hand, a DCA scheme for WATM networks has to support the statistic multiplexing to fulfill the QoS requirements of different traffic types – on the other hand a certain steadiness is required.

This papers will focus on the allocation/release of containers (section III) and on the length of the containers (section IV)

II. Dynamic Channel Allocation for wireless ATM

The DCA scheme introduced in [3] enables the base station to allocate capacity stepwise with a stepsize much smaller than the capacity offered by one frequency. The remaining capacity can be used by other BSs which results in an efficient usage of the available bandwidth. This is done by dividing one frequency into time periods of equal length which are called *containers*. The containers are generated using a TDMA scheme. Several containers build a frame which is repeated periodically (cf. figure 4).

The BS is able to allocate several containers according to the capacity requested of its WTs. The same containers are used in each frame and hold for a relatively long time which results in synchronous channels (cf. figure 3) and provides the required steadiness for the DCA.

Inside the allocated container-channels, the access of the BS and the WTs on the physical channel is co-ordinated using a *standard* MAC protocol. The signalling periods of the MAC protocol are mapped on the allocated containers (cf. figure 5). It has to be pointed out, that there is no fixed relation between a signalling period and a container – a signalling period may consists of several containers.

This leads to a two level multiplexing. Inside the allocated container-channels the BS performs a multiplexing of the traffic of its WTs, which results in a very dynamical capacity assignment to the WTs. The multiplexing of BSs (the use of different containers by different BSs) on the same physical channel happens with reduced dynamic, since the capacity requirements of a BS are steadier.

III. Capacity Allocation

The proposed DCA scheme enables the base station to allocate only the required capacity. Every time when a connection is established or released, the base station has to determine the required capacity. If it is necessary, containers are allocated or released. In WATM networks the transmission delay over the air interface is a critical item. The task is to calculate the required bandwidth (required number of containers) to be able to provide a certain transmission delay over the air interface.

In this section an approach how to determine the required capacity is introduced and its influence is evaluated by simulations. For the evaluation a scenario consisting of 37 radio cells is used, of which only the inner 7 cells are evaluated to reduce the border effects (cf. figure 6). Each cell contains 50 wireless terminals which are modelled as a two state machine. During the active state the terminal generates ATM cells using a Poisson arrival process with a mean rate of 5% (referred to the capacity offered by one physical channel), while during the passive state no cells were generated at all.

In [3] it was shown that the transmission delay is influenced by the load situation of the base station. Thus, to provide a nearly load independent transmission delay, the current situation of the base station has to be considered. This is done by using a M/D/1-model as a simplified model for the air interface.

The complementary distribution function of the transmission delay is shown in figure 7. This system was adjusted in such a way that the probability to exceed a transmission delay of 1 ms over the air interface is 10^{-4}. It can be seen that the analytic and simulation results are close together. The difference results from the signalling periods and that due to our allocation scheme the available bandwidth of the base station is adapted to the load.

Using this analysis for a certain bandwidth (number of allocated containers) the maximum load can be determined which provides a certain transmission delay. The analysis has been carried out for different bandwidths and the results are shown in figure 8. If the BS has allocated a bandwidth of 6000 ATM cells per second, the maximum utilization is around 0.45 if the probability to exceed a transmission delay of 1ms should be below 10^{-4}. This leads to a Call Admission Control (CAC) algorithm to determine the required capacity. It can be seen that the maximum utilization decreases with decreasing bandwidth.

The allocation of new containers is carried out by the base station and is based on measurements. Different algorithms can be used to select one container. On the one side, the base station can choose the best (lowest measured Radio Strength Signal Indicator (RSSI)) available container like it is done by the Dynamic Channel Selection (DCS) algorithm using in DECT systems. The resulting complementary distribution function of the transmission delay can be seen in figure 10. According to the used CAC algorithm the probability to exceed a transmission delay of 1ms should be below 10^{-4}. It can be seen that this goal cannot be reached in this case.

If always the best container is allocated, the distribution within a frame is not considered. Two different distributions can be distinguished:

clustered: the base station allocates consecutive containers

uniform: uniform distribution within a frame

In figure 10 also the complementary distribution functions for both cases are shown. It can be seen that a uniform distribution reduces the transmission delay significantly. This means that not only the container quality but also the distribution of the containers within a frame has to be considered when containers are allocated or released.

To provide a uniform distribution of the container within a frame, the available containers are organised in groups according to measured RSSI values. Out of the group with the lowest RSSI the base station chooses a container to be allocated in such a way, that the allocated containers are distributed more uniformly. The base station uses a weight for each container which indicates which container leads to a more uniform distribution. Already allocated containers are not changed since allocating a new container could disturb other connections due to the additional load on the spectrum.

The weight is calculated as follows:

$$\frac{gap_l^2 \cdot gap_r^2}{gap_t^2} \tag{1}$$

The values gap_r and gap_l represents the gap on the right and left side of the container to be allocated/released while gap_t is the total length of the gap (cf. figure 9). For each available container the corresponding weight is determined and the container with the smallest weight is allocated. When a container is released, the container is chosen which has the highest weight.

IV. Container Length

A higher number of containers per frame leads to a smaller stepsize and enables the base station to allocate capacity more precisely.

Regarding a real system, a guard time between single containers to cover the transmission delay between different base stations is necessary. The length of this interval is independent from the container length – shorter container increases this overhead.

To evaluate the influence of the container length the blocking probability simulations were carried out using the same scenario as in the previous section. All simulations were carried out with the same frame length ($3.2ms = 160\ slots$) and the number of containers per frame was varied. Thus, increasing number containers decreases the length of a single container. The guard time between two containers was $0.5\ slots$ for all simulations.

Regarding figure 11 it can be seen that in case of fixed frame length an increasing number of containers per frame increases the load of the system as long as the overhead caused by the guard time between containers can be neglected. If the containers become to small (40 containers per frame) the lost of bandwidth caused by the guard time cannot be compensated by the more precise capacity allocation and the system load decreases.

V. Conclusion

The introduced DCA scheme enables future WATM systems to use the frequency spectrum in an efficient way. In this paper a scheme to determine the required capacity was introduced to provide a certain transmission delay over the air interface. Furthermore it was shown that an uniform distribution of the containers within a frame reduces the transmission delay significantly. Therefore, the container position has to be considered whenever containers are allocated or released. Furthermore the influence of the container length on the system load has be examined.

VI. Acknowledgement

This work has been partly supported by: The German Federal Ministry of Education, Science, Research and Technology

VII. References

[1] D. Petras and A. Krämling, “Wireless ATM: Performance Evaluation of a DSA++ MAC Protocol with Fast Collision Resolution by a Probing Algorithm,” *Int. J. of Wireless Information Networks*, vol. 4, no. 4, 1997.

[2] F. Bauchot, S. Decrauzat, G. Marmigère, L. Merakos, and N. Passas, “MASCARA, a MAC Protocol for Wireless ATM,” in *ACTS Mobile Summit*, (Spain, Granada), pp. 647–651, Nov. 96.

[3] A. Krämling, M. Scheibenbogen, and T. Lohmar, “Dynamic Channel Allocation in Wireless ATM Networks,” in *International Conference on Telecommunications (ICT’98)*, (Porto Carras, Greece), pp. 286–290, June 1998.

[4] F. Priscoli, “Medium Access Control for the MEDIAN System,” in *ACTS Mobile Summit 1996*, (Granada, Spain), pp. 631–638, Nov. 1996.

[5] D. Petras, A. Krämling, and A. Hettich, “Design Principles for a MAC Protocol of an ATM Air Interface,” in *ACTS Mobile Summit 1996*, (Granada, Spain), pp. 639–646, Nov. 1996.

[6] L. French and D. Raychaudhur, “WATMnet: A prototype wireless ATM system for multimedia personal communications,” in *Proceedings of Wireless ATM Workshop*, (Espoo, Finland), Sept. 1996.

[7] M. Dinis, V. Lagarto, M. Prögler, and J. Zubrzycki, “SAMBA: a Step to Bring MBS to the People,” in *ACTS Mobile Summit*, (Denmark, Aalborg), pp. 495–500, Oct. 97.

[8] J. Mikkonen and J. Kruys, “The Magic WAND: a wireless ATM access system,” in *ACTS Mobile Summit*, (Spain, Granada), pp. 535–542, Nov. 96.

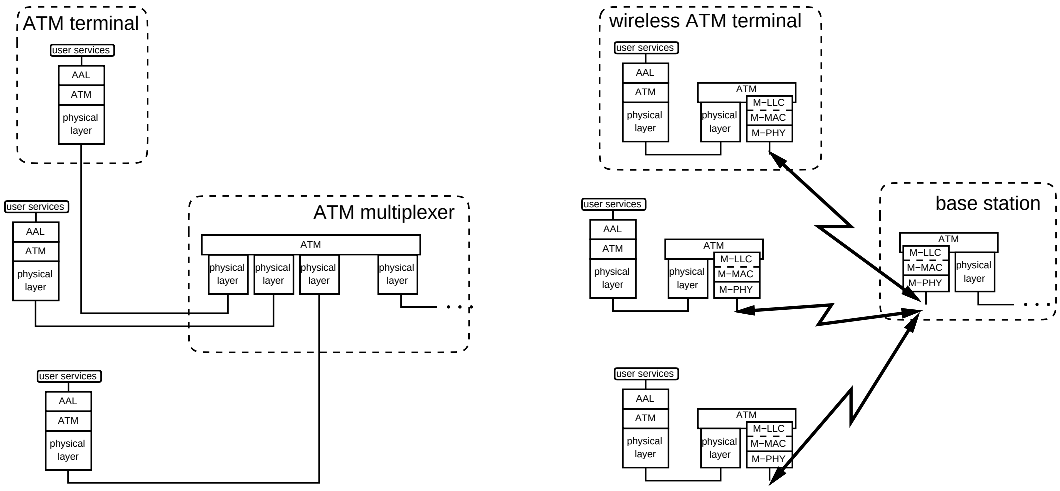

Figure 1: Correspondence between radio cell and ATM multiplexer

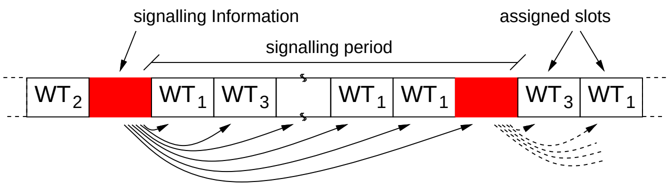

Figure 2: Structure of the signalling period

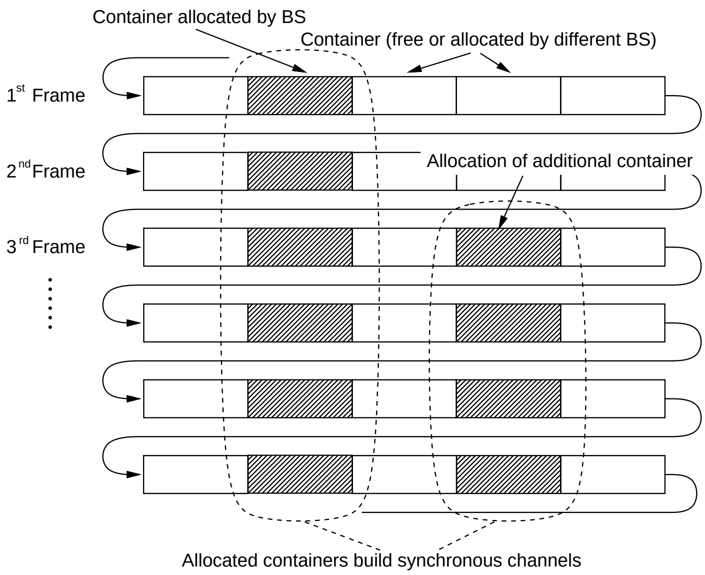

Figure 3: Allocated containers result in synchronous channels

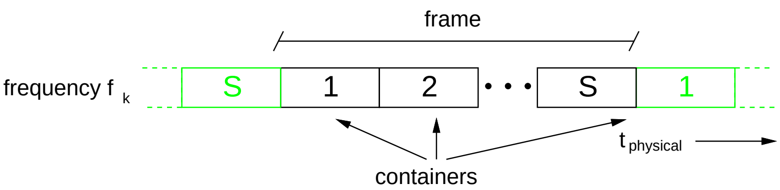

Figure 4: Frame and container structure on a physical channel

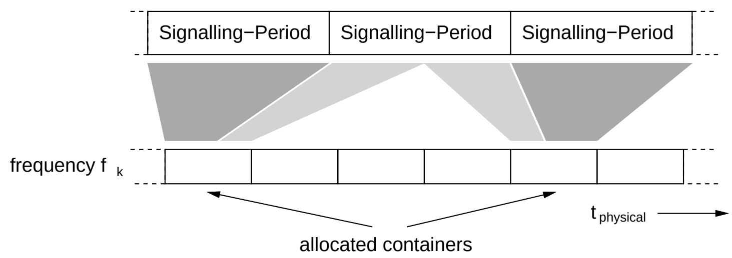

Figure 5: Mapping of signalling periods into containers

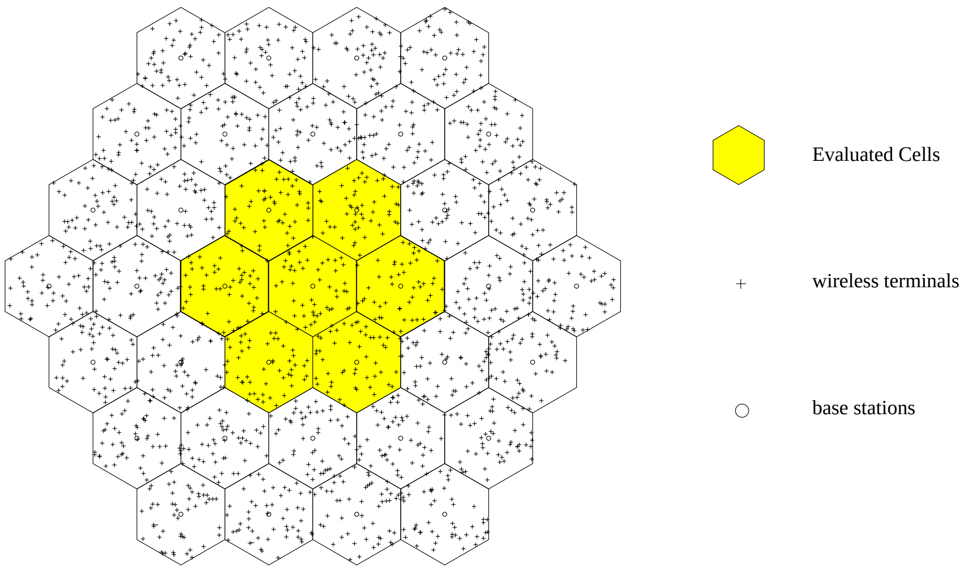

Figure 6: Simulation Scenario

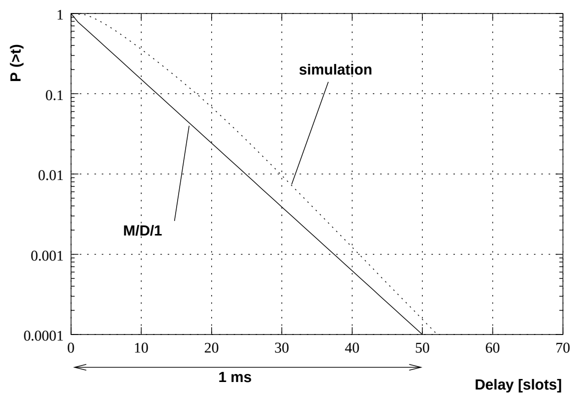

Figure 7: Complementary distribution function of the transmission delay (comparison between simulation and analysis)

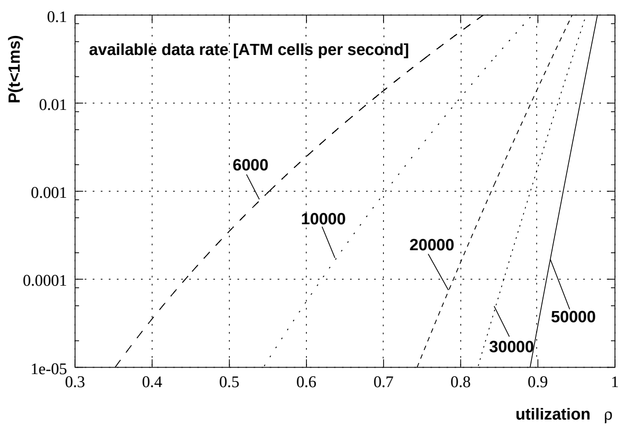

Figure 8: Influence of the available data rate on the utilization ρ

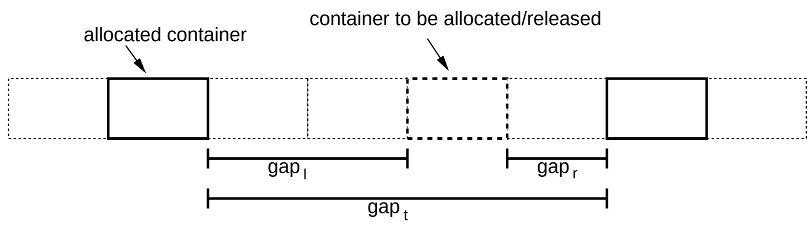

Figure 9: Calculation of the container weight

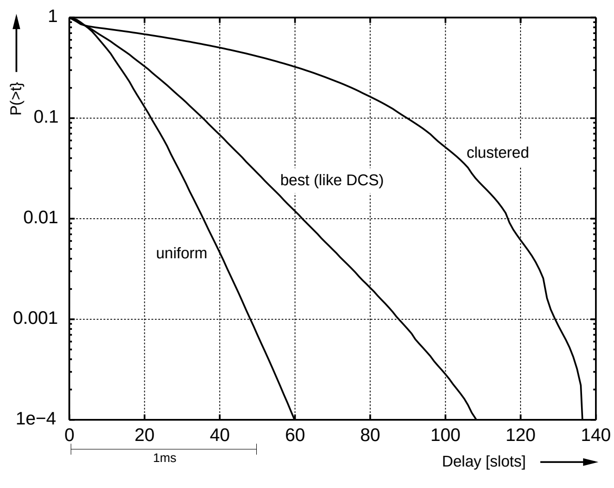

Figure 10: Influence of the container distribution within a frame on the transmission delay

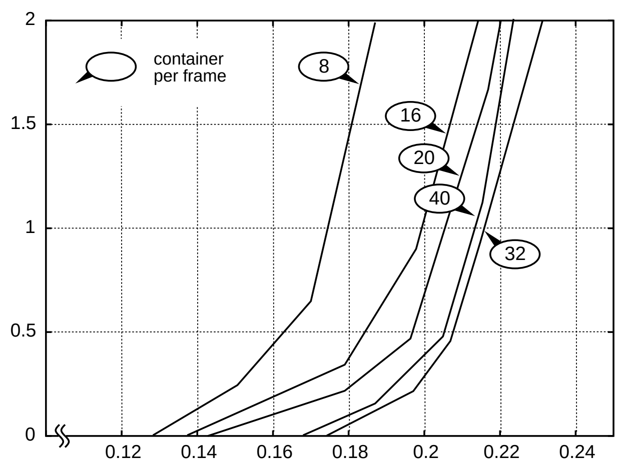

Figure 11: Grade of service versus container per frame