Teletraffic Aspects of Mobile ATM

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Abstract - **The wireless mobile ATM technologies (WATM) provide original decisions for a wideband wireless middleware, which can support wireless and mobile control of the quality of service (QoS). For the needs of network planning it is useful to know the dependances between spread-spectrum processing gain and capacity of the CDMA system. In this article we show our point of view for this problem with the results and plots that we include. We show that there isn't a linear dipendance between this two parameters.**

Keywords: **ATM, mobile ATM, W-CDMA**

I. INTRODUCTION

The term 'ATM' is widely used last few years. ATM is a technique of cell relay that is basis for compound transmission of voice, data, video, and image. The Broadband Integrated Service Digital Network (BISDN) is built on the ATM technology. ATM technology is continuously expanding with new implementations. One of the last and the most promising application is Mobile ATM. In 1996 the ATM Forum created workgroup for wireless ATM known as WATM WG. The main task of this workgroup is specification of interface structure.

II. ATM MOBILE

Mobile multimedia applications are going to become the next generation telecommunication services. The wireless mobile ATM technology (WATM) provides original decision for a wide-band wireless middleware that supports wireless and mobile control of the Quality of Service (QoS). At the same time this middleware is a platform with a different air interfaces and multi-dimensioned wireless systems. WMATM obtains signaling and data control capability over cell relay. This architecture is useful for the next generation broadband wireless systems that include broadband wireless mobility and broadband network access. WMATM is a part of IMT – 2000. IMT – 2000 is a leader on the global telecommunication market concerning next generation broadband wireless technologies [3].

Using mobile ATM network the user will have access to many different services, including connections with PSTN, Data Network, Internet and Virtual Private Networks (VPN) (Fig. 1).

Mobile ATM connection can be cheap in central urban areas and expensive in rural areas. There are some problems that must be solved before starting the Mobile ATM Network. The network needs of proper set of protocols to ensure good Quality of Service in the noisy environment with a high error rate.

The first specification for mobility management and radio-access through ATM networks (Fig. 2) is made by the ATM Forum workgroup founded in 1996.

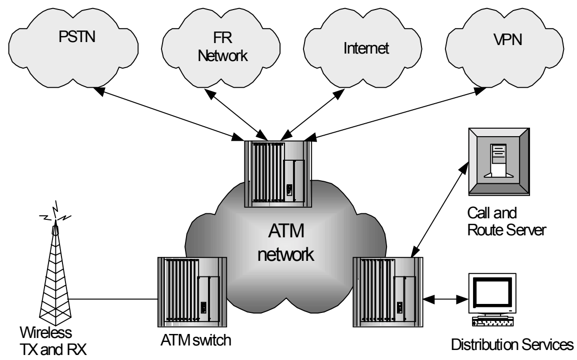

Fig. 1. Mobile ATM access

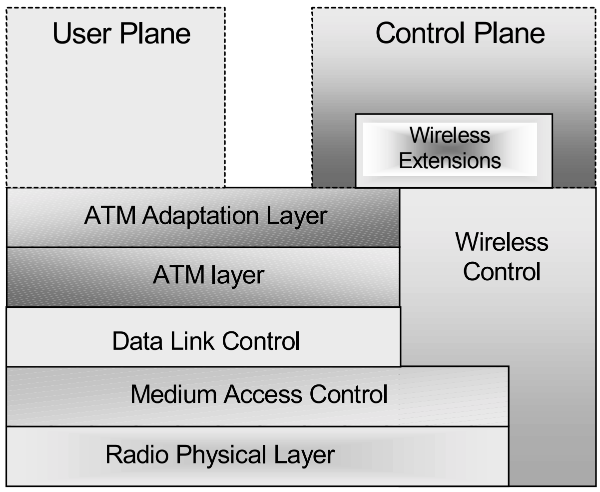

Fig. 2. User-Network interface

As it is seen from Fig. 2 the extension of user-network interface for Mobile ATM includes two major part:

1. Radio Access Layer protocol set with:
   - Radio physical layer
   - Medium Access Control layer for error detection and correction
   - Data Link Control layer for radio channel error detection and correction

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- ➢ Wireless Control Protocol layer for radio resource management.

2. Mobile ATM protocol set with:
   - ➢ Handoff control
   - ➢ Location management for mobile terminals
   - ➢ Traffic control and QoS control for mobile connections
   - ➢ Wireless network management

The radio-access through mobile ATM network is defined for portable computer or other portable device. Wireless control protocol provides intelligent network capabilities for the ATM devices including identification, roaming and information security [5].

III. WATM CELLS FORMAT

The WATM cell format is shown on Fig. 3. It is composed by two main components: header and payload. The header part of the WATM can be broken into wireless header and original ATM cell header. The wireless header is two bytes long and contains a sequence number field and a mobile control field. The wireless header is necessary for the network performance. The cell sequence number field is necessary for the Data Link Control DLC to track the erroneous cells and to perform selective Automatic Repeat reQuest ARQ.

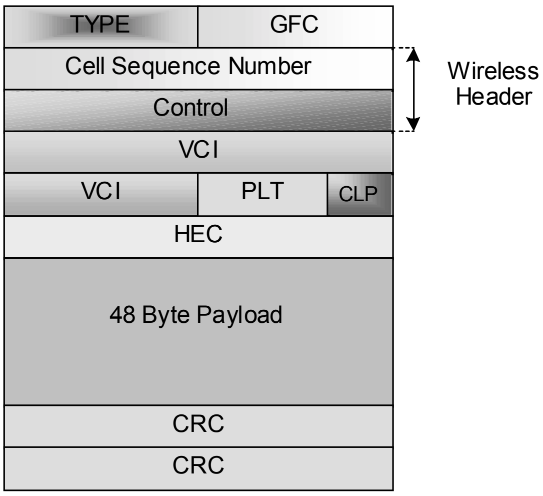

Fig. 3. Mobile ATM cell format.

The mobile control field is necessary for network mobility management. Keeping the original ATM cell header structure will, on the other hand, simplify the cell format conversion at the base station and mobile terminal. At the same time, the Virtual Channel Identification (VCI) can be used to identify a base station when the mobile terminal is the handoff initiator [1].

IV. SURVEY OF BLOCKING PROBABILITY IN WCDMA

The technology that supports broadband mobile access to the end-user is WCDMA. It applies Code Division Multiple Access (CDMA) technique with broadened spectrum. This technology is applied in UMTS systems. It supports transfer of large quantities of data from/to the mobile station. When the frequency band is wide each WCDMA user could use a few services simultaneously. The services could be optimized to the desired bit rate and to the predefined Quality of Service (QoS).

Broadened spectrum support is based on linear modulation with pseudo random sequences also known as (Pseudo Noise Code or PN Code). The rate of the sequence is much higher that the rate of the resulted signal. Broadened sequences (PN Codes) are assigned to each end-user and are used as unique authentication code. They have low coefficient of correlation. Therefore the signals from different end-users can be sent in common frequency band and distinguished by inverse transformation with their PN Codes. Walsh codes are used as pseudo random sequences or PN Codes.

With WCDMA it is possible to reach coefficient of frequency band reuse equal to 1. The capacity is slightly decreasing when distortion level increases. The spectrum usage is high. Quality of Service increases due to the “soft handoff” functionality. Higher quality of the voice signal in air interface and higher degree of signal security and disturbances are reached due to the CDMA technology. It is necessary to note that all the advantages of the WCDMA require complicated signal processing at the end-user terminal, strict synchronization, precise control of the power of the signals emitted by the mobile station [4].

In the CDMA cellular systems the number of channels is not fixed. The capacity (number of users) depends on the degree of interference. Blocking occurs when the reverse link multiple access interference power reaches a predetermined level. The value of interference power is used to maintain accessible signal quality. If the total user interference at a base station receiver exceeds some threshold, the system denies access of the next user who attempts to place a call. Because the number of users (the traffic) at a given time is random and the interference power from a certain user is Random Value (RV) the blocking probability leads to an estimate of the average number of the active users. The received signal power level is subject to shadowing that causes the received signal level to be a RV-type. It is known as Erlang capacity of the CDMA cell or sector. The determination of the capacity depends on the assumptions about the probability distributions of the call traffic and user interference.

Let try to derive some blocking probability formulae that will prove the advantages of the WCDMA.

Consider a CDMA cell with M active users. Let η shows the load of the CDMA system. The quality of the channel available to the (M+1)-st mobile user is being characterized by the value of the random variable Z. If this random variable exceeds some threshold value, then the channel becomes unavailable (blocked) to the (M+1)-st user. This way the blocking probability for the (M+1)-st mobile CDMA user is equal to the probability that Z has reached some threshold value Z_0. Z_0 is a function of η_0, where η_0 is a threshold value of the interference parameter.

There are two approximation methods for gathering the signal between mobile user and base station: Gaussian approximation and Lognormal approximation.

For the Gaussian approximation it can be written [2]:

$$Q_Z(x) \approx Q(x) = \int_x^{\infty} \frac{1}{\sqrt{2\pi}} \exp^{-t \ /2} dt \qquad (1)$$

where $Q_Z(x)$ is a notation for the complementary cumulative distribution function of the standardized version of the RV Z.

For the probability of blocking B_{CDMA} with Gaussian distribution the following formula is valid [2]:

$$B_{CDMA} = Q\left(\frac{\frac{W}{R_b}(1-\eta_0) - \overline{M}\,\overline{\alpha_r}\,\rho_{med} \exp^{\frac{1}{2}\beta^2\sigma_{dB}^2}(1+\xi)}{\sqrt{\overline{M}\,\overline{\alpha_r^2}\,\rho_{med}^2 \exp^{2\beta^2\sigma_{dB}^2}(1+\xi')}} \right) \qquad (2)$$

where $\overline{M}$ is the Erlang capacity, W is the expanded frequency band [Hz], $R_b = 1/T_b$ is the data rate, η_0 is the threshold value for the interference, α_r is a random variable, which describes the active voice feedback. It is assumed that $\overline{\alpha_r} = 0{,}4$ and $\overline{\alpha_r^2} = 0{,}31$. Also, $\rho_{med} = \exp^{\beta m_{dB}}$, $\beta = (\ln 10)/10$, $m_{dB} = E_b / N_0$ is a median of the Gaussian probability distribution, E_b is the power of one bit from the received signal [W-sec], N_0 is a single-side noise Spectral density [W/Hz], σ_{dB} is a standard deviation.

$$\xi = \frac{\text{total other - cell received (median) power}}{\text{total same - cell received (median) power}} \qquad (3)$$

$$\xi' = \frac{\text{total other - cell mean square received power}}{\text{total same - cell mean square received power}} \qquad (4)$$

The interference between two mobile users located in a different cells could be expressed using first- F=1+ξ and second- F=1+ξ'order frequency reuse factors.

The blocking probability is given by the threshold value function of the interference parameter and the threshold value of the cell load. Let us compare B_{CDMA} in the cases of Gaussian and Lognormal approximations. When B_{CDMA} = 1%, Gaussian and Lognormal approximations give similar results. This is the reason to recommend Gaussian Approximation in such cases.

An important point, when the blocking probability of CDMA cellular systems is analyzed, is the relation between dimension of the expanded frequency band and the number of users in the current cell (Erlang capacity). It will be interesting to see the result when frequency band is expanded/reduced twice and how this will reflect over the number of served users.

V. Results and Analisys

Fig. 4 depicts the average number of users versus blocking probability in a case of a single cell (ξ=ξ'=0). The graphics are obtained using Eq. (1) and (2) with parameters: $m_{dB} = E_b / N_0 =$ 7dB, σ_{dB}=2,5dB, R_b=9,6kbit/s, X_0=0,9, $\overline{\alpha_r} = 0{,}4$, $\overline{\alpha_r^2} = 0{,}31$. Plots for a different values of

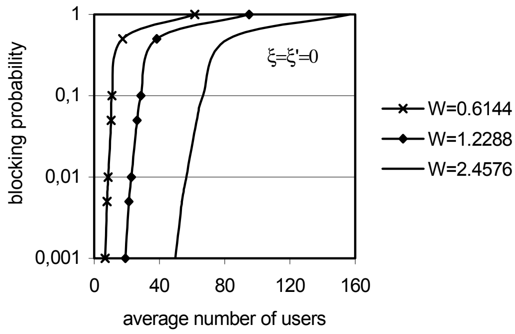

Fig. 4 Average number of users versus blocking probability

W - 0,6144 MHz, 1,2288 MHz and 2,4576 MHz are shown in the figure. If the frequency band is expanded two times, (W=2,4576 MHz) i.e. spread-spectrum processing gain-W/R_b will increase, then the served mobile users for an exact value of blocking probability is about 2,5 times more than the case when W=1,2288 MHz. When B_{CDMA}=0,001, the served mobile users are 2,6 times more. When B_{CDMA} = 0,01, than 2,5 times more end-users will be served. When B_{CDMA}=0,1, this number is 2,3. An exception is the case when B_{CDMA}=1. In this case the number of mobile users is about 1,65 times higher. Let us decrease the extended frequency band two times (W=0,6144 MHz). For B_{CDMA}=0,001, the served users are 2,8 times less. When B_{CDMA}=0,01, the served users is 2,7 times less. When B_{CDMA}=0,1, the value of the served users is 2,5 times less.

Fig. 5 presents B_{CDMA} for multiple cells (ξ=ξ'=0,55) using Eq. (1) and (2). The parameters have the same values as explained above. The number of the mobile users, that are served for a different values of B_{CDMA} and W are less than in the case of a single cell.

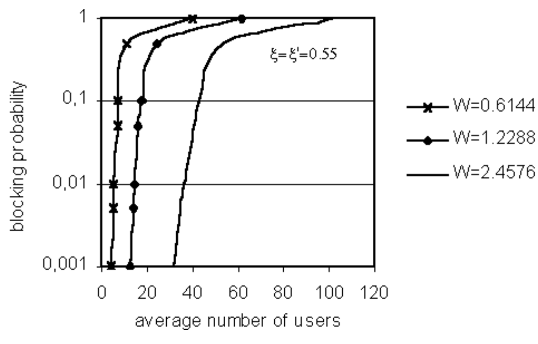

Fig. 5 Average number of users versus blocking probability

When we increase two times the extension of the spectrum for different values of B_{CDMA}, on the other hand, we serve the same number of mobile users as in the case of a single cell. The results are the same if the spectrum is decreased.

VI. Conclusion

An approach to obtain some new relations about the influence of the spread-spectrum processing gain and the capacity of the a CDMA system is proposed in this work. To our best knowledge such an approach does not exist in the literature.

From the experiments and results that we have obtained we can conclude that the ratio between the number of the users, who are served when we increase or decrease the extended frequency band are independent from the values of ξ and ξ', i.e. they don't depend of the type of cell (single cell or multiple cells). On the other hand the number of the served users for an exact value of B_{CDMA} and W are different for these two cases - single cell or multiple cells. That is because when ξ=ξ'=0,55, the interference between mobile users is high and the frequency reusing factors from the first and second order are F=1,55. An important conclusion is that the relation between increasing and decreasing the extended frequency band and the number of mobile users, who are served when we have an exact value of the blocking probability, is not linear. At the same time, the number of users who are served for a given value of blocking probability is different, with a factor of 0.2. For this reason we must choose an optimal value for the extended frequency band in which the signals from the mobile users to the base stations are radiated.

References

[1] G. Bao, Lang Tong, "Protocol-Aided Channel Equalization in Wireless ATM", *IEEE Selected Areas in Communications, vol. 18, no. 3, march 2000.*

[2] J. Sam Lee, L. E. Miller, "CDMA Systems Engineering Handbook", *1998.*

[3] W.W. Lu, Qi Bi, "Wireless Mobile ATM Technologies for Third-Generation Wireless Communications", *IEEE Communications Magazine, vol. 37, no. 11, November 1999.*

[4] BTC-Team, "Application of systems with spread-spectrum and code-division multiplexing in the cell-mobile and wireless subscriber access networks", *Radio and television, no. 3/2000, 1998.*

[5] D. McDysan, "ATM Theory and Application", *McGraw-Hill, 1999*