Improved Integral Channel Allocation Algorithms in Cellular Communication Systems Enabling Multimedia QoS Services

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Abstract – While bandwidth management in cellular communication systems has been thoroughly examined for voice channel admission by developing several DCA (Dynamic Channel Assignment) strategies, there are a few only efforts investigating assignment and management of multimedia enabling channels in wireless communications. However, the increasing demand for these advanced services in cellular networks such as data, MMS and video transfers raises the problem of efficient bandwidth management in terms of channel assignment meeting QoS criteria. Several algorithms for supporting QoS services have been presented in the literature based mainly on bandwidth reservation and capacity management for enabling efficient handoff over cellular networks. The goal of this paper is to develop and investigate, however, novel integral DCA algorithms for supporting data (e.g. files) and video (video viewing, video conference) transmission with Quality of Service (QoS), and their evaluation through a prototype advanced statistical simulation environment for cellular communications. Moreover, we analyze the dynamic and distributed channel allocation strategies for enabling advanced multimedia services based on signal purity measures and interference measurements. Finally, the performance of these suggested algorithms evaluated through a proposed prototype simulation environment is discussed.

Key-words: Cellular network, DCA, Quality of Service, signal measurements, multimedia services, simulation

1 Introduction

1.1 Channel assignment in cellular networks

The cellular network capacity (how many users can be served at the same time) is strongly connected with channel availability. The available bandwidth (interpreted as the number of available channels) is restricted but the number of Mobile Users (MUs) is increasing day by day[1].

The channel assignment to cells or MUs is one of the fundamental resource management issues in a mobile communication system [2].

The main goals of a channel assignment strategy are:

- Minimize the probability of blocking new calls (no available channel for a new user)
- Minimize the probability of dropping ongoing calls (due to unsuccessful handoff)
- Minimize the interference between co-channel users

Three are the most known channel assignment strategies according to literature:

- FCA - Fixed Channel Assignment
- DCA - Dynamic Channel Assignment
- HCA - Hybrid Channel Assignment

Based on a pre-estimated traffic, a set of channels are permanently allocated to each cell intensity with regard to FCA [3,4,5,6,7]. In DCA [3,8,9,10,11], the available channels are assigned to new and existing users in a dynamically manner. Thus, DCA strategy is more flexible compared to dynamically change of traffic conditions. Finally, HCA [3,12] combines the features of FCA and DCA.

1.2 Quality of Service (QoS) in advanced services

In recent years, the user demand for advanced mobile services such as data transfer, video, etc, bring out much more the problem of the available bandwidth. The algorithm design for efficient bandwidth management is a critical issue for multimedia cellular network design.

Quality of service (QoS) can be studied from many different points of view. In cellular communications the bandwidth management is a key concept for achieving the desired QoS. Many bandwidth management strategies have been proposed such us bandwidth reservation, reducing handoff dropping probability [13,14,15], etc. In these studies, the handoff dropping probability in combination with the new call admission are the most critical factors that affect the QoS assurance for advanced cellular services [13,14,15]. In general, QoS prescribes the required capacity (bits per second) that has to be above a specified threshold until the service normal termination. The QoS constraints are based on the type of each new call service. The dynamically changing network traffic conditions make difficult the optimal performance of bandwidth management algorithms. In our approach, the proposed algorithms ensure the required capacity until the normal service termination. Most of the studies found in [16] do not take in consideration the signal measures for supporting QoS as our study does.

1.3 Channel Allocation Algorithms

Modern services over wireless networks, such as video calls, require high bandwidth availability. Video frame rate, resolution and colour depth determine the required bit rate for the assigned channels. In order to deliver video based on the above characteristics, the bit rate must be guaranteed. Many algorithms for supporting advanced services have been presented in the literature based mainly on bandwidth reservation and capacity management.

Network services have different demands in terms of channel capacity. Video is the more demanding service especially when there is no tolerance in the required Quality of Service. Due to the restricted bandwidth, efficient strategies for channel assignment for supporting all the type of services must be applied. In many introduced strategies, a predicted amount of channels are reserved in order to support future requests for multimedia services or for supporting ongoing multimedia calls. Many of these approaches have the drawback of rejecting new call request in order not to drop ongoing calls that are based on Quality of Service constraints.

The Multimedia wireless services can be classified in different categories based on the required bandwidth and QoS. According to [17], two classes (I and II) correspond to real and non real time services. In [17] an integrated adaptive framework is proposed that consists of two schemes. The first scheme reserves a part of the bandwidth in order to support handoffs with high priority. The other scheme migrates bandwidth in order to achieve load balancing over the network. The idea of adaptive bandwidth management is not new and can be found in earlier studies [18,19]. In these studies the Adaptive Bandwidth Reservation and a provision scheme are presented respectively. In Adaptive Bandwidth Reservation, the bandwidth reservation for the most demanding request is made from adjacent cells. The provision scheme is based on the MU mobility prediction.

The proposed algorithms in [17], are categorized as online due to the fact that the control decisions and measurements for the current network conditions take place at real time. On the other hand, the offline approach is not efficient because it needs complete knowledge of the future conditions for an online problem. In [17], the individual computation of the total requested bandwidth for services that belong to class I (real time services) and II (non real time services) respectively is formulated as follows:

$$B_R^1 = \sum_{j \in W_{set\_I}} \left(B_j \times N_j \right) \qquad (1)$$

$$B_R^2 = \sum_{k \in W_{set\_II}} \left(B_k \times N_k \right) \qquad (2)$$

where B_R^1 and B_R^2 represent the total requested bandwidth for class I,II services respectively. N_j,B_j correspond to the number of handoff requests of class I,II of j type of services. The N_k, B_k, represent the number of handoff requests of class I,II for k type of services. The total reservation bandwidth for both classes can be obtained from the formula:

$$B_R = \sum_{i=1}^{2} B_R^i \qquad (3)$$

When a wireless network is close to congestion, the requested resource capacity can not be reserved in order to satisfy every active MU. As a result, the calls must be served in a prioritized base. Usually, the higher priority is assigned to handoff calls compared to new call requests [20]. The most known admission control strategies found in the literature for priority calls can be classified as Handoff Queues or Guard Channel schemes [20]. In the same study, the Preferential Treatment with Interference Guard Margin is presented and proposed. In Interference Guard Margin scheme, a new call and a low priority call are faced and served differently in terms of accepted interference level.

More precisely, the requirement for a new call admission is not to exceed the upper limit of the interference with threshold I-th (system tolerance).

On the other hand, an augmented interference I-th' is required for a lower priority call. The interference margin between I-th and I-th' represents the guard margin which is the base for the limited access of the lower priority calls.

In order to achieve some kind of optimality in call admission and handoff, the selected approach has to take also in to consideration the possible future network status after the application of the selected strategies [21]. Assume that a wireless network has many available resources for servicing new call admissions. ***The successful call admission does not guarantee the sufficient support (non drop) of any ongoing calls in the future*** [21]. In the same study, a general decision-theoretic approach for call admission is presented and proposed. In [21], different traffic classes are partitioned in a number of QoS classes. The QoS classes are represented by a number of layers. Thus, video streams can be represented as multi-layer scalable flows, adapted to current network conditions [21]. Additionally, the admission control is formulated as Markov Decision Process with transition probability based on current state. In the same approach, the calls in progress within a cell represent the cell state.

The evolution of wireless networks for supporting multimedia services and the need for efficient resource managements is presented in [22]. Two known strategies for QoS resource management are the Complete Sharing and Complete Partitioned [22]. In Complete Sharing, the available bandwidth is shared among the various traffic classes. This strategy has the disadvantage that when a traffic class is temporarily overloaded, the rest of the other classes will be affected adversely in terms of quality. On the other hand, according to Complete Partitioned approach the whole bandwidth is clearly divided for supporting individually the traffic classes. Using this approach the system suffers from wasted bandwidth. To overcome the above drawbacks, a hybrid approach combines the Complete Sharing and Complete Partitioned features. In this approach the bandwidth is allocated dynamically in order to support efficiently the traffic variations [22].

2 An Advanced Prototype Simulation Platform for Multimedia Bandwidth Management

2.1 Introduction

In our model, the cellular network consists of N cell with a Base Station (BS) in each cell center. Connected users may exist in various positions within a cell according to a pre-defined mesh of spots. The network modeling is focused to network procedures that support the main user activities.

2.2 Basic network procedures

The simulation model supports four major network procedures (services) which are:

- New call arrival
- Call Termination
- Call Reallocation
- User Movement

New call arrival is based on Poisson distribution (eq. 4) with regard to a daily traffic model.

$$P(x) = \frac{e^{-\lambda} \cdot \lambda^{x}}{x!} \quad (4)$$

where λ, represents the new call arrival rate. After a new call arrival, the selected channel assignment scheme is activated. Based on the selected scheme, the algorithm searches for an available channel, calculates CNR between MU and BS, and finally calculates the interference between current MU and other co-channel users. If the signal purity conditions (Carrier to Noise plus Interference Ratio Threshold - CNIR Threshold) are fulfilled, the channel is finally assigned to that MU. Multiple channels are assigned in case of video services. An unsuccessful channel assignment procedure causes a new blocked call.

The call termination procedure examines the call holding time for each service (except data service) and disconnects the current MU if this time is expired.

In every simulation step, the signal quality for each connected user is examined. As in new call arrival, CNR and CNIR for one or more channels (for the same MU) are calculated. If the final CNIR for current MU is below the pre-defined threshold, the call reallocation procedure tries to find another accepted channel. When this attempt is not successful, the call is dropped.

Finally, a user movement is generated according to Gaussian distribution (eq. 5).

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2} \quad (5)$$

2.3 User mobility model

As mentioned before, the λ parameter represents the new call arrival rate. This rate is analogous to the time of the day. A fixed set of simulation time steps represents a whole day according to representation of a defined real time slice with a single simulation step. Each zone represents a specific percentage period of the day. The parameter λ, changes with regard to each active zone in simulation time.

2.4 Implementation architecture

2.4.1 Agent-Based Systems

An Agent can be described as a computational system that interacts autonomously with its environment and operates for the goal for which it has been designed [23]. It percepts the environment conditions, acts according to that conditions, interprets perceptions and solves problems [24]. Agents are entities that are smaller than a typical application [25]. Additional information about the most known characteristics of agents such as adaptability, autonomy, interactivity, etc, can be found in [26,27,28,29,30]. In modern problems, a number of agents is needed for modeling all the system aspects and so the multi-agent systems emerged. Multi-agent systems (MASs), can be faced as a loosely coupled network of problem-solver entities [31] that collaborate together with the common goal to solve the whole problem. According to literature, agent technology has been used for distributed resource management in telecommunication systems [32,33,34].

2.4.2 Agent-based model for cellular networks

A key point for the simulation system development is the adaptation to real network behavior. In a real network, when a user tries for a call, at the same time another service for another user is terminated and so on. Due to that fact the above mentioned network procedures must be implemented in a concurrent manner.
Every network procedure, is independent from each other, acts autonomously, interacts with environment (cellular network), has its own goals and thus can be implemented as agent.

2.4.3 Multi-Agent Multi-layered Architecture

The architecture of the prototype simulation system is based on the multi-agent concept, adapted to real cellular network behavior.
According to this architecture, the whole system is divided to three layers (fig. 1):

- Layer 1 (core layer) which represents the cellular network environment and where the basic events take place.
- Layer 2 consists of four agents that implement the concurrent events and describe the network behavior.
- Layer 3 which contains the Control Agent.

The control agent controls and synchronizes the Agent activities. Contains a clock for agent activation in layer-2 and assures the correct execution order of any supplementary function.
Each network agent is implemented as thread within the Java Virtual Machine (JVM) environment.
Control agent synchronizes the following three actions (fig. 2):

- Initial procedures (supplementary procedures for each new simulation step)
- Network Agents (New call arrival, Call reallocation, User movement and Call termination)
- Final procedures (after completion of each simulation step)

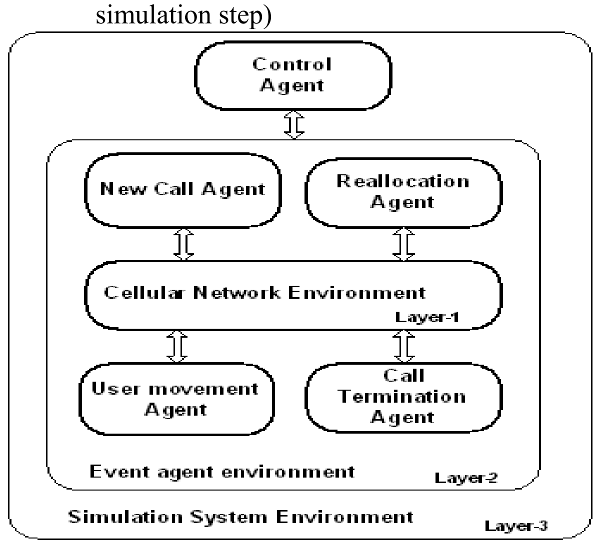

Fig. 1 - Multi-Agent Layered Architecture

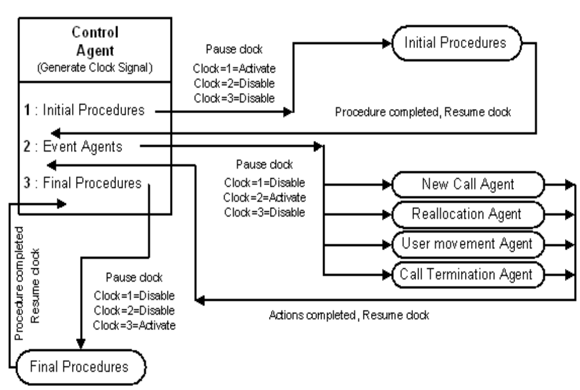

Fig. 2 Control Agent operation

Another specialized thread called clock schedules all the concurrent network events based on the Priority Queue Time Division Multiplexing (PQ-TDM) algorithm [35,36]. According to this mechanism, the computational time is distributed among the active threads that represent the network agents. Thus, the competitive cellular network environment is represented (competition for shared network resources such as channels).

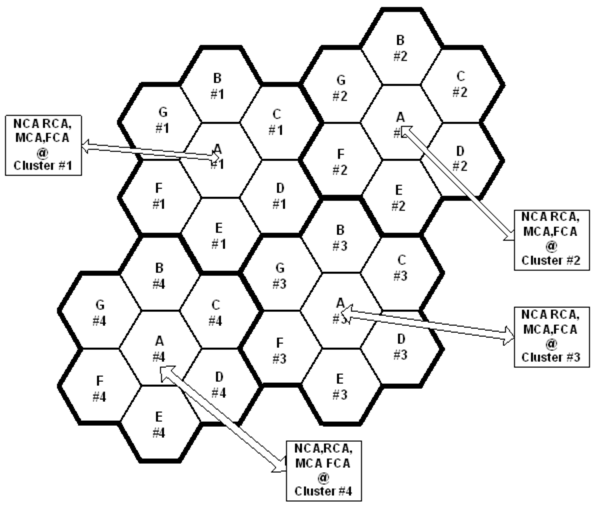

Fig.3 Network agents in cluster areas

Figure 3 shows how the four basic network agents are spread in network cluster areas.

3 Proposed DCA algorithms for supporting advanced services with QoS

3.1 Supported novel DCA schemes

Our simulation system supports four basic and two hybrid DCA schemes which are:

Basic DCA schemes

- Unbalanced (UDCA)
- Balanced (BDCA)
- Best CNR (CDCA)
- Round Blocking (RDCA)

Hybrid DCA schemes

- CNR and Balanced hybrid (CBDCA)
- Hybrid DCA (HDCA)

In Unbalanced version[37], the network makes one try for user connection within the initiated cell (where the new call occurred).

Round blocking scheme is an extension of unbalanced variation which searches also for an accepted channel in the neighbor cells. The algorithm stops when a successful channel assignment is made.

To maintain balanced network conditions, the Balanced variation[38] is developed. According to this algorithm, the final attempt for a MU connection is made within the cell (initiated or neighbor) with the minimum congestion.

In Best CNR variation[38], the system calculates the CNR between MU and BS of initiated or neighbor cell. The final attempt for connection is made within the cell with maximum CNR between BS and MU. Thus, we achieve better shield of MU from interference.

The goal of CNR and Balanced hybrid variation[38] (fig. 4) is to shield more the channel from interference and at the same time to maintain balanced traffic conditions in the network.

```
Try to find the best three least congested cells within the neighbor cells

if not possible,
        apply Best CNR for all cells,
        end of algorithm
Else
Apply Best CNR in the best three least congested cells
```

Fig. 4 - CNR and Balanced hybrid variation

The hybrid DCA algorithm[38] (fig. 5), exhausts all the possibilities for a successful channel assignment in the neighbor and maintains balanced traffic conditions in the network.

```
Cellconggroup[] =Data for congestion percentage and position of the six
                neighbour cells
/*check if it is possible to find the best three least cong. Cells*/
zero_counter=0
Loop
  Get First/Next Cell in Cellconggroup[]
  If Current Cellconggroup[]=0 Then zero_counter++
End Loop

/*if not possible, apply BCDCA for all neighbour cells*/
If (zero_counter>3) Then
  Compute cell with BCDCA Algorithm
  Try to connect current MU in cell with BCDCA
Else
/*locate the three best least congested cells */
  Loop (x=1..3) {for finding the three best least Congested neighbour
            cells}
  Min= congestion in cellconggroup[1]
  Position=1
  Loop
        Get First/Next cell in Cellconggroup[]
         If Current neighbour cell congestion < Min Then
                Min=Current neighbour cell congestion
                Position=Current neighbour cell
        position
            End If
        END Loop
  threeleastcong[]=new least congested cell
  Exclude Min cell from Cellconggroup[]
/* try connection in the current least congested cell */
  Try to connect current MU in threeleastcong[x]
/*if the connection is successful do not search in the rest cells*/
  If the connection is successful Then Exit from Loop
  End Loop
```

Fig. 5 Hybrid DCA variation

3.2 Proposed DCA variations for supporting Multimedia services

3.2.1 Service Generation

The Poisson distribution determines the potential users to be connected. Based on three different Gaussian distributions the system generates the type of service (voice, data, video) and the requested capacity (video) or size (data). Initially, the type of service is generated (table 1).

X	Service Type
[0.5,0.5]	Voice
[-0.8,-0.5)U(0.5,0.8]	Data
[-1.0,-0.8)U(0.8,1.0]	Video

Table 1. Service type generation

If the service is voice, a typical channel is given to that user. In case of Data service the required file size for transfer is generated (table 2).

X	File size
[-0.5,0.5]	100Kbytes
[-0.7,-0.5)U(0.5,0.7]	500Kbytes
[-0.9,-0.7)U(0.7,0.9]	1Mbyte
[-1.0,-0.9)U(0.9,1.0]	5Mbyte

Table 2. File size generation

For video service, the corresponding required capacity (table 3) is generated.

X	Capacity
[-0.5,0.5]	384000bps
[-0.7,-0.5)U(0.5,0.7]	768000bps
[-0.85,-0.7)U(0.7,0.85]	1536000bps
[-1.0,-0.85)U(0.85,1.0]	3072000bps

Table 3. Capacity generation

3.2.2 Required channel capacity based on services constraints

Each user service requires a different bit rate in relation with bandwidth and signal to noise plus interference ratio. Channel capacity can be calculated using the known Shannon-Hartley formula which is

$$C = B \cdot \log_2(1+\gamma) \qquad (6)$$

Where B is the channel bandwidth in Hz and γ is the signal to noise plus interference ratio in the case of cellular network. We assume also that the transmitted signal is in digital form.
For the above mentioned services the required capacity can be calculated as follows:

Voice channels
The required capacity for the voice channels can be defined as:

$$V_c = BPS * SPS \qquad (7)$$

where BPS is the bits per sample and SPS is the samples per second. For example, in order to transmit voice data with 8 bit per sample and 22.05KHz Sampling frequency we need a capacity of 160.4Kbps.

Video channels
The required capacity is:

$$Vc = imX*imY*cd*fps \qquad (8)$$

where imX is the X resolution of the picture in pixels, imY is the Y resolution of the picture in pixels, cd is the color depth in bits and fps is the number of required frames (still images) per second.

3.2.3 Multimedia Unbalanced DCA (MUDCA)

A voice service requires only a single channel. The call holding time (CHT) is resulted from exponential distribution with selected mean value. The CHT is combined with current simulation time, where each simulation step corresponds with a constant real time slice. The call termination agent, checks in every simulation step the call progress of each connected user in terms of simulation time. When this time is expired, the call is terminated.
For each new data service, a single channel is assigned. This is because the service is not real time. In each simulation step, the capacity of the assigned channel is calculated. According to this capacity, an amount of data is subtracted (fig. 6) from the previous requested (previous simulation step). When the initially requested data are transferred, the service is terminated. In this case, the CHT is replaced with active channel capacity in combination with the transferred data.
When a video service is initiated, the requested capacity is covered using multiple channels according to the selected DCA scheme. This is a real time service, requires QoS and so the initially requested capacity must be warranted until the call termination. The algorithm for channel assignment calculates the total capacity among various channels and stops the assignment when the requested capacity is covered or the six neighbor cells have been checked. Figure 7, shows the algorithm for channel allocation that used for new video call arrival or video call reallocation.

```
//Data call progress and termination
//a specific real time slice is assigned to a single sim step
//SD=Simulation step duration (sec)
Get remaining data (RD) to be transferred (user registry)
Get current channel capacity (CCAP)//connected ch.
New_RD=RD-(CCAP*SD)
```

```
If (RD<=0)
  Terminate Data Call
Else
  Do nothing
```

Fig. 6. Data call progress and Termination

The reallocation agent checks one by one each connected channel for that service and tries to reallocate only specific channels that not fulfill the CNIR threshold. After the partial reallocation the new total capacity (remaining and new channels) is re-calculated. If the new capacity is not accepted, the reallocation agent continuous to search for appropriate channels.

```
//new channel assignment for video call
Rcap=requested capacity by video call (QoS service)
Attempt=0
Capserved=0 //total served capacity
While ((Capserved<Rcap) && (attempt<=6*Chnum))
  Find an available channel
  Newserved=0
  If available channel is found
    Calculate CNR between BS and MU
    Calculate interference from other co-channels
    Calculate final CNIR
    If (CNIR>=CNIR threshold)
      Calculate current channel capacity
      Newserved=current channel capacity
      Store channel attributes in User registry
    End if
  End if
  Attempt++
  If (Newserved>0) Capserved+=Newserved
End while
If (Capserved>=Rcap) succeed=1
  Else succeed=0
```

Fig. 7. Channel assignment algorithm for video call

3.2.4 Multiple Cell-Multiple channel Multimedia Unbalanced DCA (MMDCA)

Assume that a video call is established in cell-1 (fig. 8). The total required capacity for that call is served by several assigned channels that belong in both cells (initial and neighbour). Thus, the required capacity in bps is:

$$C_{T(bps)} = \sum_{i=a}^{d} C_{1i} \quad (9)$$

The concept of calculating the current available capacity of a selected channel is based on the known Shannon's formula which is:

$$C_{bps} = 2B\log_m\left(1+CNR\right) \quad (10)$$

where C is the channel capacity in bps, B is the channel bandwidth in Hz, m is based on the transmitting symbol levels and CNR is the Carrier to Noise Ratio. Each channel capacity is based on current signal conditions (CNR and CNIR), therefore a number of appropriate channels for a video service must be provided for each call.

With this technique, low dropping and blocking probability can be achieved due to multiple channel availability among different neighbour cells.

In MMDCA variation, the MUDCA is used among different cells in the neighbor. Thus, multiple channels can be assigned from different cells for supporting a video call. In figure 8, a video call is in progress in cell-1. The required capacity for that call is served via 1_a,1_b,1_c and 1_d channels that belong to cell-1 and cell-2. With this technique, low dropping and blocking probability can be achieved due to multiple channel availability among different neighbor cells.

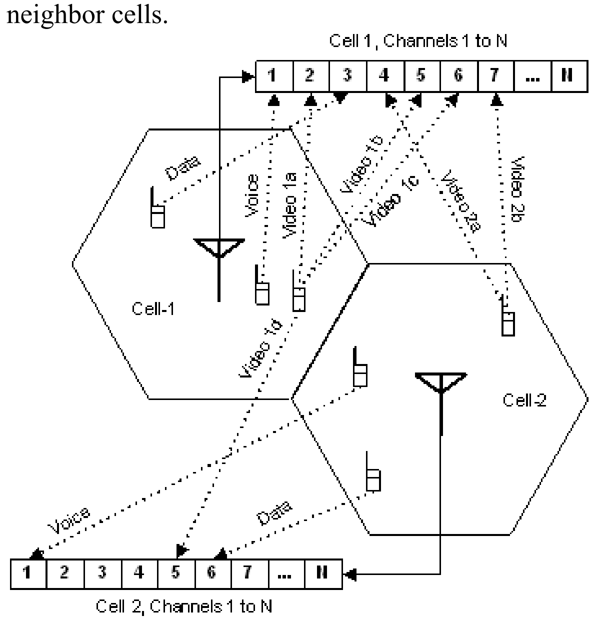

Fig. 8. - Multiple channel assignment (MMDCA)

Reallocation procedure (RC) optimizes the network performance by checking the communication conditions of every connected MU. Figure 8 illustrates also a partial channel reallocation for a video service of a connected MU. The required capacity is served initially by channels 1_a to 1_d. Due to unaccepted signal conditions (CNIR threshold), channel 1_b in cell-1 is disconnected. The network assigned two other alternative channels with total capacity equal to the disconnected channel and thus:

$$C_{TA(bps)} = C_{1a} + C_{1b} + C_{1c} + C_{1d} \quad (11)$$

$$C_{1b.1} + C_{1b.2} = C_{1b} \quad (12)$$

$$C_{TB(bps)=}C_{1a} + C_{1b.1} + C_{1b.2} + C_{1c} + C_{1d} = C_{TA(bps)} \quad (13)$$

where C_{1b} is the capacity of the rejected channel and $C_{1b.1}$ and $C_{1b.2}$ are the new assigned channels that offer total capacity equal to initial capacity of C_{1b}. Based on this concept, only partial call reallocation is needed (selected channels) and so better network performance is achieved.

4 Statistical metrics

Blocking probability constitutes a measure for GoS[39] (Grade of Service) level or Quality of Service[40]. When a new call arrival occurs and the network can not allocate a channel then we say that this call is blocked. The blocking probability is calculated from the ratio

$$P_{blocking} = \frac{number\ of\ blocked\ calls}{number\ of\ calls} \quad (14)$$

The *dropping probability* is also an additional and very important characteristic of the cellular network. When a call is in progress and the required quality conditions are not met then this call is obligatory driven to termination. The dropping probability is calculated from the ratio

$$P_{fc} = \frac{number\ of\ forced\ calls}{number\ of\ calls - number\ of\ blocked\ calls} \quad (15)$$

Additional statistical metrics found in literature [38] can be used to measure the results accuracy using outliers [41], model requirements [42] and simulation model behavior such as periodicity and standard deviation progress [38]. In this paper we present some preliminary results and so only the basic metrics have been used.

5 Simulation results

5.1 Sample executions

We have simulated a cellular network with 50 potential users in each cell and 32 channels per cell. For advanced services such as Data and video we have used the MUDCA variation. For voice services, we have simulated all the proposed DCA variations.

A new video service has initiated in cell 13 (fig. 9a, 9b). The reallocation agent checks each video channel individually and reports that no reallocation is needed. After the reallocation check, the user is moved to cell 1 (reconnection from cell 13 to 1), user position 3.

```
>>>NEW VIDEO[cell 13][MU positioin in UR 35]=384000,
CALL HOLDING TIME=65.43178, Current Simulation Time:0
Checking . . .
*** [cell 13][MU positioin in UR 35], BASIC channel (10),
capacity=191674.52 <<ACCEPTED>>
*** [cell 13][MU positioin in UR 35], Extra-Cell:13, Extra-Channel:11,
capacity=184368.0 <<ACCEPTED>>
*** [cell 13][ MU positioin in UR 35], Extra-Cell:13, Extra-Channel:12,
capacity=186047.28 <<ACCEPTED>>
Reporting... for [cell 13][ MU positioin in UR 35],
Requested CAPACITY=384000.0, Lost CAPACITY=0.0,
New Served=384000.0, Good capacity=562089.75 %GOOD,
No Reallocation Needed
---> Disconnect VIDEO [cell 13][ MU positioin in UR 35] for MOVE
@[@[ NEW VIDEO MOVEMENT successful, giving [cell 1][ MU
positioin in UR 3], OLD HOLDING TIME:65.43178
. . . . . .
```

Fig. 9a. Video service initiation

After a new reallocation check (fig. 9b), two video channels are not accepted (rejected) and so reallocation must be made only for these channels. The algorithm finds two alternative channels, computes the corresponding capacity and finally decides for another reallocation trial or not. When the CHT is expired, the service is terminated.

```
Checking . . .
*** [cell 1][ MU positioin in UR 3], BASIC channel (3),
capacity=173036.02 <<ACCEPTED>>
*** [cell 1][ MU positioin in UR 3], Extra-Cell:1, Extra-Channel:1,
capacity=165086.77 <<REJECTED>>
*** [cell 1][ MU positioin in UR 3], Extra-Cell:1, Extra-Channel:4,
capacity=176465.86 <<REJECTED>>
Reporting... for [cell 1][ MU positioin in UR 3], Requested
CAPACITY=384000.0, Lost CAPACITY=341552.62,
New Served=42447.375, Good capacity=173036.02 %BAD!,
Reallocation is needed . . .
REALLOCATING [cell 1][ MU positioin in UR 3] . . .
{0} - ### SUGGESTED Basic, [cell 1][ MU positioin in UR
3],Channel:16, Requested Capacity:210963, Capacity:168810.73
Total Capacity (SUGGESTED Channels):168810.73
{1} - ### SUGGESTED Extra, [cell 1][ MU positioin in UR 3],
ExtraCell:1, Extra Channel:17, Capacity:173610.4
Total Capacity (SUGGESTED Channels):342421.12
Final record to [cell][user]=[ cell 1][ MU positioin in UR 3]
. . .
Checking . . .
*** [cell 1][ MU positioin in UR 3], BASIC channel (16),
capacity=168810.73 <<ACCEPTED>>
*** [cell 1][ MU positioin in UR 3], Extra-Cell:1, Extra-Channel:17,
capacity=173610.4 <<ACCEPTED>>
*** [cell 1][ MU positioin in UR 3], Extra-Cell:1, Extra-Channel:3,
capacity=173036.02 <<ACCEPTED>>
Reporting... for [cell 1][ MU positioin in UR 3], Req.CAP=384000.0,
Lost CAPACITY=0.0, New Served=384000.0, Good
capacity=515457.12 %GOOD, No Reallocation Needed
---> VIDEO DISCONNECT Due to END OF TIME, [cell 1][ MU
positioin in UR 3]
```

Fig. 9b. Video reallocation

5.2 Performance results

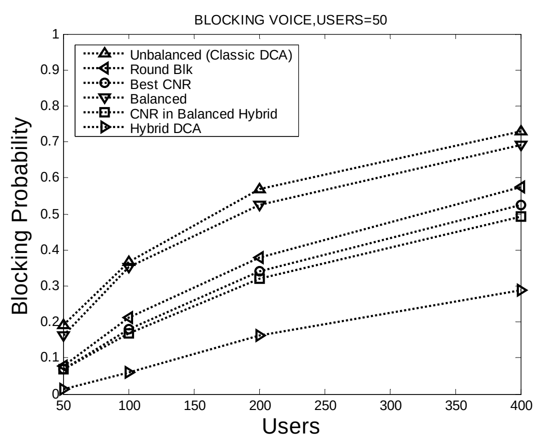

Fig. 10. Blocking probability for VOICE services

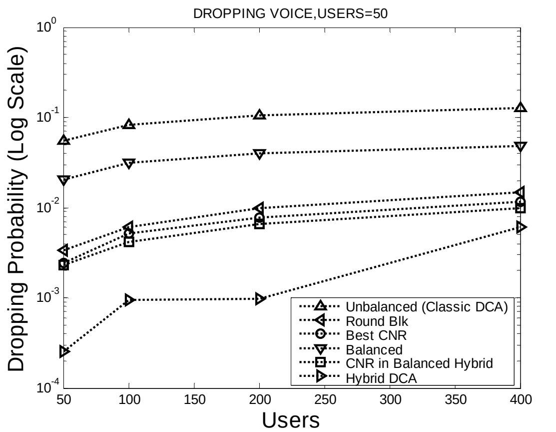

Fig. 11. - Dropping probability for VOICE services

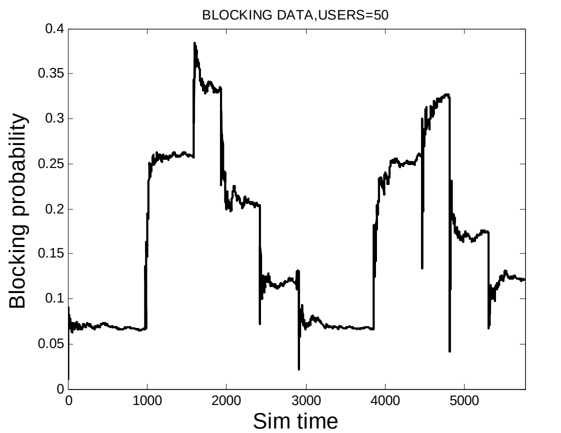

Fig. 12. Blocking probability for DATA services (2 traffic days - MUDCA)

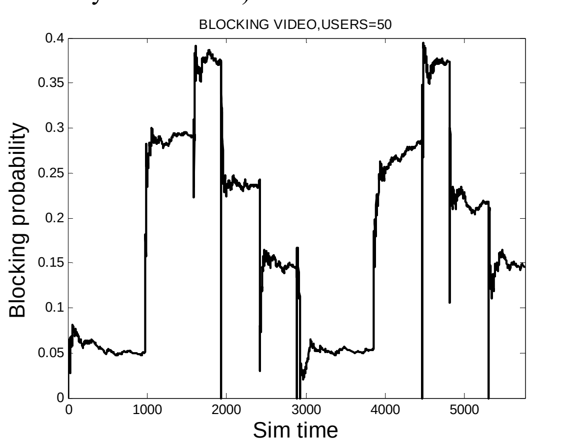

Fig. 13. Blocking probability for VIDEO services (2 traffic days - MUDCA)

Table 4 shows the DCA scheme combinations for the offered network services.

Scheme	VOICE	DATA	VIDEO
1	UDCA	UDCA	MUDCA
2	UDCA	UDCA	MMDCA
3	UDCA	RDCA	MUDCA
4	UDCA	RDCA	MMDCA
5	RDCA	RDCA	MMDCA

Table 4 DCA scheme combinations

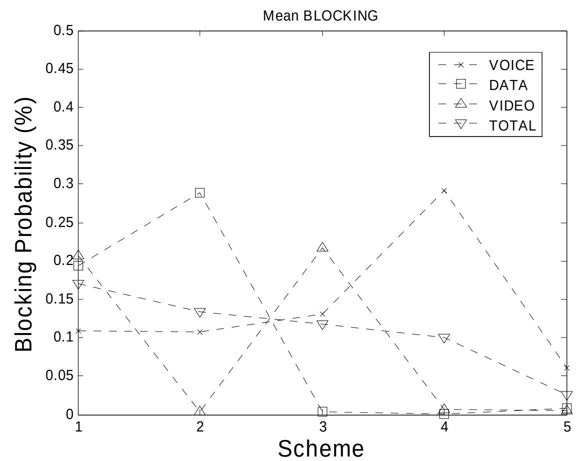

Fig. 14 Blocking probability for DCA scheme combinations

Figure 14 shows that a different DCA strategy must be applied for each type of service in order to achieve best performance for all services in terms of blocking probability.

6 Conclusions & Future work

Novel efficient hybrid algorithms for supporting advanced multimedia QoS services such as Data and Video transmission over cellular networks have been investigated in this research based on suitably extending known DCA strategies. Contrary to the most recent studies for supporting multimedia services with QoS, our proposed algorithms are based on signal and interference measurements such as CNR and CNIR for providing the requested capacity for a selected service, following an integral view and not the handoff specific aspect as usually. Developing new statistical evaluation metrics adapted to QoS multimedia communications and corresponding suitable efficient DCA algorithms is under analysis by the authors

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