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SIMULATION MODELS OF CALL ADMISSION CONTROL SCHEMES USING GPSS

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***Abstract*:** *In cellular wireless networks, a variety of channel allocation schemes have been developed for achieving high capacity with minimal interference. The choice of channel allocation scheme impacts the performance of the system, particularly as how calls are managed when a mobile user is handed off from one cell to another. Call Admission Control schemes take into account the effect of handoffs in the performance of the system, particularly call blocking probability and call dropping probability. In this study, we present simulation models and programs of some popular Call Admission Control schemes using GPSS simulation tool.*

Keywords: GPSS, Call Admission Control, Modelling using simulation.

1. Introduction

Mobile communication systems normally contain three key constituent elements: *mobile station* (MS), *base station* (BS), and *mobile switching center* (MSC). The MS may be any handheld device, such as a mobile phone, portable computer, personal digital assistant (PDA), car communication systems, notebook, or any other device capable of communicating via omni-directional radio waves within a given frequency band using a prescribed communication protocol [1-17].

The geographical area covered by a mobile communication network is divided into several regions known as cells, as shown in figure 1. Each cell has either one or more antennae at its center that are wire-connected to a BS. The BS controls the communications between all MSs inside a particular cell. To facilitate communications beyond the coverage of a single cell, all BSs within a large geographical area are controlled by an MSC, which stores information relevant to all MSs under its control and acts as a gateway to external networks such as the

Internet, public switched telephone network (PSTN), or any other MSC. BSs are normally connected to an MSC by high-speed optical fiber transmission lines [1-17].

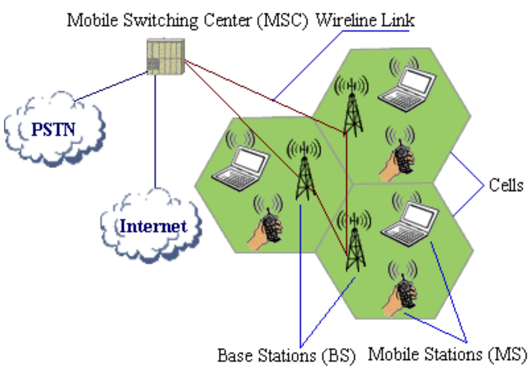

Figure 1: Architecture of a cellular network.

The radius of a cell is primarily governed by the power level of the signal. When two cells overlap, an imaginary handoff boundary is assumed along the common chord. In the ideal case, when the radii of all neighboring cells are assumed to be the same, the shape of each cell, formed by the imaginary handoff boundary lines, is a perfect hexagon. In reality, the radius of a cell varies in different directions due to the terrain, co-channel interference effects, and noise. Moreover, depending on location and capacity requirements, different signal power levels may be used in neighboring cells, leading to a heterogeneous cell configuration [1-17].

When a mobile user moves from one cell to another, a handoff occurs. With the active participation of the mobile hosts and the MSC, the base stations are instrumental in initiating and finalizing handoffs. One of the key elements in providing QoS guarantees is to provide a faultless handoff. When there is no channel available for handoff connection, the connection will be dropped. Dropping a handoff connection is generally considered to have a more negative impact from users' perception than rejecting a newly requested connection [1-17].

The mobile hosts in a cell communicate directly with the corresponding BS that has the responsibility of handling all demands for service originating in the cell. In particular, the BS is in charge of negotiating QoS parameters, of performing admission control, and of reserving resources for ongoing connections. This could mean denying access to new connections in order to provide an acceptable level of service to active connections. A new connection that is denied access into the network is said to be blocked. The call blocking probability (CBP) is an important QoS parameter in wireless networks [1-17].

The call dropping probability (CDP) is the possibility that the network will deny resources to a connection after it is in progress. A connection may be dropped during a handoff, when the host moves from a cell into a new cell that is too congested to support more traffic [1-17].

A good scheme must minimize handoff dropping probability because from mobile user's perspective dropping an ongoing connection is less desirable than blocking a new connection. Moreover, the blocking probability of new calls should be reduced and channel utilization maximized [1-17].

Call Admission Control refers to the task of deciding whether or not a certain connection request will be admitted into, and supported by, the network. Prioritized call admission control schemes restrict the number of new calls accepted to decrease the probability of handoff call failure [1-17].

Simulation Models

A computer simulation is a computation that models some real or imagined system over time. Computer simulation makes it possible to analyze systems that would be expensive, dangerous or even impossible to construct prototypes for. The goal of simulation is to evaluate performance characteristics of the system. The behavior of a system as it evolves over time is studied by developing a simulation model. This model usually takes the form of a set of assumptions concerning the operation of the system. Simulation can be used in the design of a new system to check the design variants before implementation. It can also be used in the analysis of an existing system to investigate different modes of operation outside the real system.

In this study, a GPSS World simulation tool was used to simulate some of the most popular Call Admission Control schemes. GPSS World is based on the seminal language of computer simulation, GPSS, which stands for General Purpose Simulation System [18]. This language was developed primarily by Geoffrey Gordon at IBM around 1960, and has contributed important concepts to every commercial discrete event Computer Simulation Language developed ever since. GPSS World is a direct descendent of GPSS/PC, an early implementation of GPSS for personal computers. Since its introduction in 1984, GPSS/PC and its successors have saved thousands of users millions of dollars. GPSS World is the worthy descendent of these early simulation environments.

In the following sections, simulation models and simulation programs for some popular Call Admission Control schemes are presented. It is assumed that voice calls require 1 channel.

Fully Shared Scheme (FSS)

In this scheme, handoff and new calls are treated equally. All available channels are shared by handoff and new calls. This scheme does guarantee the required dropping probability for handover calls, but minimizes call dropping probability and has the advantage of efficient utilization. Flowchart of the simulation model is given in figure 2.

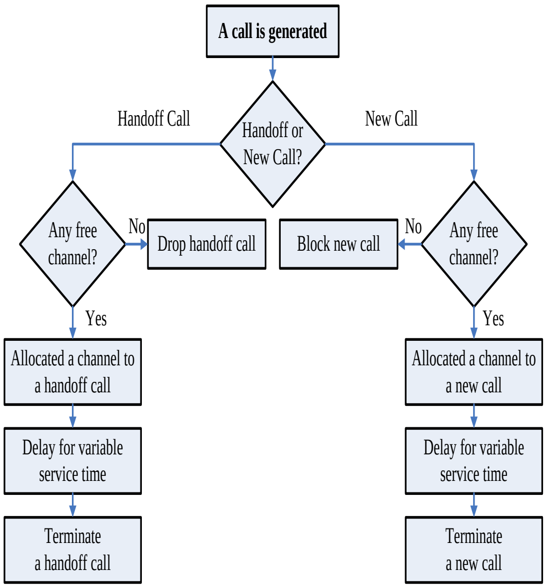

Figure 2: Simulation model of FSS.

Simulation program of FSS:

```
IAINT        EQU 1
MST              EQU 180

                 TCH STORAGE 100
                 GENERATE (EXPONEN
TIAL (1,0,IAINT) TRANSFER .5,NC,HO

NC               TEST GE X$ACH,100,NCAC
                 SAVEVALUE  NCB+,1
                 TERMINATE  1

NCAC             SAVEVALUE  NCA+,1
                 SAVEVALUE  ACH+,1
                 ENTER      TCH,1
                 ADVANCE
(EXPONENTIAL(1,0,MST))
                 LEAVE      TCH,1
                 SAVEVALUE  ACH-,1
                 TERMINATE  1

HO               TEST GE X$ACH,100,HOAC
                 SAVEVALUE  HOB+,1
                 TERMINATE  1

HOAC             SAVEVALUE  ACH+,1
                 SAVEVALUE  HOA+,1
                 ENTER      TCH,1
                 ADVANCE
(EXPONENTIAL(1,0,MST))
                 LEAVE      TCH,1
                 SAVEVALUE  ACH-,1
                 TERMINATE  1
```

1.1 Fully Shared Scheme with Handoff Queuing (FSS_HOQ)

This scheme is an extension of FSS. In this scheme, priority is given to handoff attempts by allowing queuing of handoff calls in case all channels are occupied. Queuing of handoff calls will result in a lower call dropping probability compared to FSS. When a channel is released in a cell, it is assigned to the next handoff call attempt waiting in the queue (if any). If more than one handoff call attempt is in the queue, the first-come-first-served queuing discipline is used. If no channel was allocated to the handoff call in the queue, it will be dropped after a specific period of time, td. So, if time spent by handoff in the queue, th, is greater or equal to td, then handoff call is dropped. A new call is blocked if no channel is available in the cell. Flowchart of the simulation model is given in figure 3.

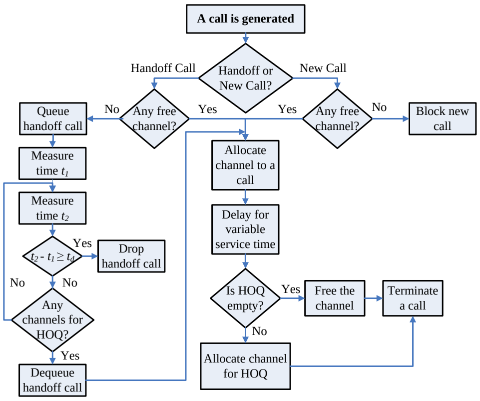

Figure 3: Simulation model of FSS_HOQ scheme.

Simulation program of FSS_HOQ:

```
IAINT       EQU 1
MST         EQU 180
HQINT       EQU 20

            TCH STORAGE 100
            GENERATE
(EXPONENTIAL(1,0,IAINT))
            TRANSFER   .5,NC,HO

NC          TEST GE X$ACH,100,NCAC
NCBL        SAVEVALUE  NCB+,1
            TERMINATE  1

NCAC        SAVEVALUE  NCA+,1
            SAVEVALUE  ACH+,1
            ENTER      TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,NCNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

NCNOQH      SAVEVALUE  ACH-,1
            TERMINATE  1

HO          TEST GE X$ACH,100,HOAC
            QUEUE Handoff
            MARK
            SAVEVALUE  QH+,1

ISCHAV      ADVANCE 0.1
            TEST GE
X$ACHQH,1,NCHAV
CHAV        SAVEVALUE  ACHQH-,1

            ENTER      TCH,1
            DEPART Handoff
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,QNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

QNOQH       SAVEVALUE  ACH-,1
            TERMINATE  1

NCHAV       TEST GE
M1,HQINT,ISCHAV
            DEPART Handoff
            SAVEVALUE  QH-,1
HODR        SAVEVALUE  HOB+,1
            TERMINATE  1

HOAC        SAVEVALUE  ACH+,1
            SAVEVALUE  HOA+,1
            ENTER      TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,HNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

HNOQH       SAVEVALUE  ACH-,1
            TERMINATE  1
```

1.2 Fully Shared Scheme with Handoff and New Call Queuing (FSS_HOQ_NCQ)

This scheme is an extension of FSS_HOQ. In this scheme, both handoff and new calls are queued. Queuing of new calls will result in a lower call blocking probability and higher call dropping probability compared to FSS_HOQ. In this scheme handoff calls are treated in same way as in FSS_HOQ. A new call is queued if no channel is available in the cell. When a channel is released in a cell, it is assigned to the next handoff call attempt waiting in the queue. If there is no handoff waiting in the queue, the channel is assigned to the next new call waiting in the queue (if any). If more than one new call is in the queue, the first-come-first-served queuing discipline is used. If no channel was allocated to the new call in the queue, it will be blocked after a specific period of time, tb. So, if time spent by a new call in the queue, tn, is greater or equal to tb, then new call is blocked. Flowchart of the simulation model is given in figure 4.

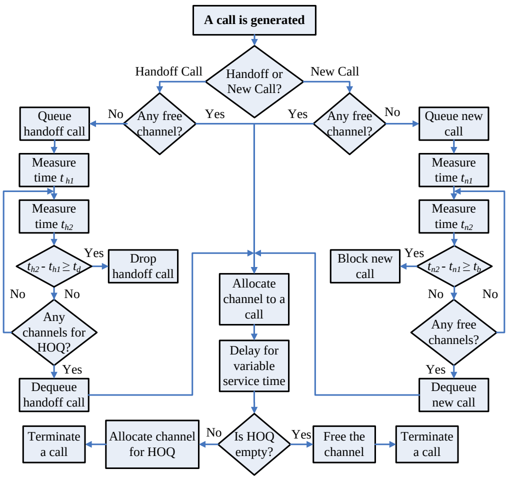

Figure 4: Simulation model of FSS_HOQ_NCQ scheme.

Simulation program of FSS_HOQ_NCQ:

```
IAINT       EQU 1
MST         EQU 180
HQINT       EQU 20
NCINT       EQU 20

            TCH STORAGE 100
            GENERATE
(EXPONENTIAL(1,0,IAINT))
            TRANSFER   .5,NC,HO

NC          TEST GE X$ACH,100,NCAC
            QUEUE Newcall
            MARK
NCISCHAV    ADVANCE 0.1
            TEST GE
X$ACH,100,NCCHAV
            TEST GE
M1,NCINT,NCISCHAV
            DEPART Newcall
NCBLCK      SAVEVALUE  NCB+,1
            TERMINATE  1

NCCHAV      SAVEVALUE  ACH+,1
            ENTER      TCH,1
            DEPART Newcall
```

```
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE     TCH,1
            TEST GE X$QH,1,NCNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

NCAC        SAVEVALUE  ACH+,1
            ENTER     TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE     TCH,1
            TEST GE X$QH,1,NCNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

NCNOQH      SAVEVALUE  ACH-,1
            TERMINATE  1

HO          TEST GE
X$ACH,100,HOACPT
            QUEUE Handoff
            MARK
            SAVEVALUE  QH+,1

HOISCHAV    ADVANCE 0.1
            TEST GE
X$ACHQH,1,HONOCHAV
HOCHAV      SAVEVALUE  ACHQH-,1

            ENTER     TCH,1
            DEPART Handoff
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE     TCH,1
            TEST GE X$QH,1,HONOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1


HONOCHAV TEST GE
M1,HQINT,HOISCHAV
            DEPART Handoff
            SAVEVALUE  QH-,1
HODROP      SAVEVALUE  HOB+,1
            TERMINATE  1

HOACPT      SAVEVALUE  ACH+,1
            SAVEVALUE  HOA+,1
            ENTER     TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE     TCH,1
            TEST GE X$QH,1,HONOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

HONOQH      SAVEVALUE  ACH-,1
            TERMINATE  1
```

1.3 Guard Channel Scheme (GCS)

In this scheme priority is given to handoff attempts by assigning Ch channels exclusively for handoff calls among the C channels in a cell. The remaining C – Ch channels are shared by both new calls and handoff calls. A new call is blocked if the number of available channels in the cell is less than or equal to Ch when the call is originated. A handoff attempt is unsuccessful if no channel is available in the target cell. Flowchart of the simulation model is given in figure 5. In the flowchart, C represents total number of channels, Ca represents number of already allocated channels and Ch represents number of channels reserved for handoff calls.

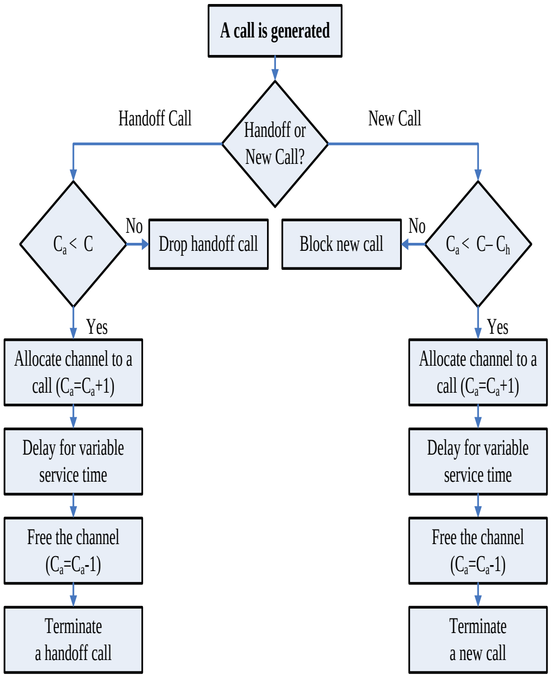

Figure 5: Simulation model of GCS.

Simulation program of GCS:

```
IAINT        EQU 1
MST          EQU 180

             TCH STORAGE 100
             GENERATE
(EXPONENTIAL(1,0,IAINT))
             TRANSFER   .5,NC,HO

NC           TEST GE X$ACH,80,NCAC
             SAVEVALUE  NCB+,1
             TERMINATE  1

NCAC         SAVEVALUE  NCA+,1
             SAVEVALUE  ACH+,1
             ENTER      TCH,1
             ADVANCE
(EXPONENTIAL(1,0,MST))
             LEAVE      TCH,1
             SAVEVALUE  ACH-,1
             TERMINATE  1

HO           TEST GE X$ACH,100,HOAC
             SAVEVALUE  HOB+,1
             TERMINATE  1

HOAC         SAVEVALUE  ACH+,1
             SAVEVALUE  HOA+,1
             ENTER      TCH,1
             ADVANCE
(EXPONENTIAL(1,0,MST))
             LEAVE      TCH,1
             SAVEVALUE  ACH-,1
             TERMINATE  1
```

1.4 Guard Channel Scheme with Handoff Queuing (GCS_HOQ)

In this scheme, same channel-sharing method is used as in GCS, except that queuing of handoff calls is allowed if necessary. Queuing of handoff calls will result in a lower call dropping probability compared to GCS. If there is no available channel for handoff call in a cell, handoff call is queued. When a channel is released in a cell, it is assigned to the next handoff call attempt waiting in the queue (if any). If more than one handoff call attempt is in the queue, the first-come-first-served queuing discipline is used. If no channel was allocated to the handoff call in the queue, it will be dropped after a specific period of time, td. So, if time spent by handoff in the queue, th, is greater or equal to td, then handoff call is dropped. A new call is handled the same way as in GCS. Flowchart of the simulation model is given in figure 6. In the flowchart, C represents total number of channels, Ca represents number of already allocated channels and Ch represents number of channels reserved for handoff calls.

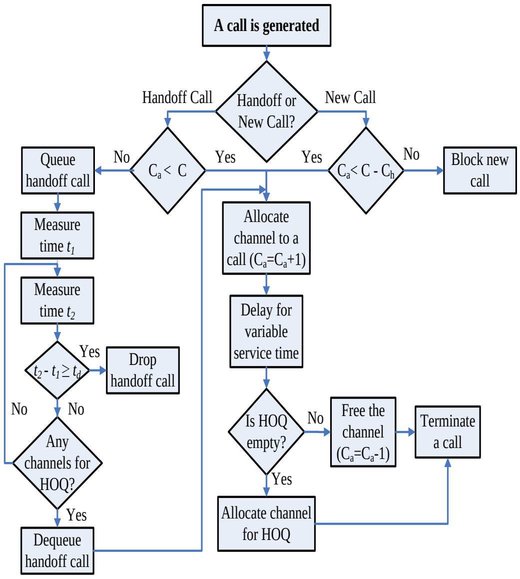

Figure 6: Simulation model of GCS_HOQ scheme.

Simulation program of GCS_HOQ scheme:

```
IAINT       EQU 1
MST         EQU 180
HQINT       EQU 20

            TCH STORAGE 100
            GENERATE
(EXPONENTIAL(1,0,IAINT))
            TRANSFER   .5,NC,HO

NC          TEST GE X$ACH,80,NCAC
NCBL        SAVEVALUE  NCB+,1
            TERMINATE  1

NCAC        SAVEVALUE  NCA+,1
            SAVEVALUE  ACH+,1
            ENTER      TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,NCNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

NCNOQH      SAVEVALUE  ACH-,1
            TERMINATE  1

HO          TEST GE X$ACH,100,HOAC
            QUEUE Handoff
            MARK
            SAVEVALUE  QH+,1

ISCHAV      ADVANCE 0.5
            TEST GE
X$ACHQH,1,NCHAV
CHAV        SAVEVALUE  ACHQH-,1

            ENTER      TCH,1
            DEPART Handoff
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,QNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

QNOQH       SAVEVALUE  ACH-,1
            TERMINATE  1

NCHAV       TEST GE
M1,HQINT,ISCHAV
            DEPART Handoff
            SAVEVALUE  QH-,1
HODR        SAVEVALUE  HOB+,1
            TERMINATE  1

HOAC        SAVEVALUE  ACH+,1
            SAVEVALUE  HOA+,1
            ENTER      TCH,1
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
            TEST GE X$QH,1,HNOQH
            SAVEVALUE  ACHQH+,1

            SAVEVALUE  QH-,1
            TERMINATE  1

HNOQH       SAVEVALUE  ACH-,1
            TERMINATE  1
```

1.5 Guard Channel Scheme with New Call Queuing (GCS_NCQ)

In this scheme, same channel-sharing method is used as in GCS, except that queuing of new calls is allowed if necessary. Queuing of new calls will result in a lower call blocking probability compared to GCS. If there is no available channel for the new call, new call is queued. When a channel is released in a cell, it is assigned to the next new call waiting in the queue (if any). If more than one new call is in the queue, the first-come-first-served queuing discipline is used. If no channel was allocated to the new call in the queue, it will be blocked after a specific period of time, tb. So, if time spent by new call in the queue, tn, is greater or equal to tb, then new call is blocked. Flowchart of the simulation model is given in figure 7. In the flowchart, C represents total number of channels, Ca represents number of already allocated channels and Ch represents number of channels reserved for handoff calls.

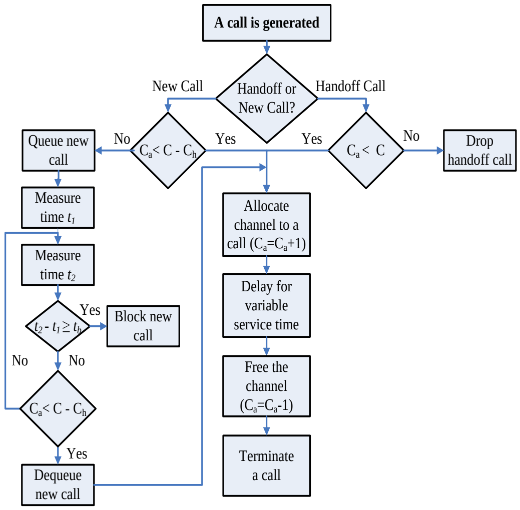

Figure 7: Simulation model of GCS_NCQ scheme.

Simulation program of GCS_NCQ scheme:

```
IAINT       EQU 1
MST         EQU 180
NCINT       EQU 20

            TCH STORAGE 100
            GENERATE
(EXPONENTIAL(1,0,IAINT))
            TRANSFER   .5,NC,HO

NC          TEST GE X$ACH,80,NCAC
            QUEUE Newcall
            MARK
NCISCHAV    ADVANCE 0.1
            TEST GE
X$ACH,80,NCCHAV
            TEST GE
M1,NCINT,NCISCHAV
            DEPART Newcall
NCBLCK      SAVEVALUE  NCB+,1
            TERMINATE  1

NCCHAV      SAVEVALUE  ACH+,1
            ENTER      TCH,1
            DEPART Newcall
            ADVANCE
(EXPONENTIAL(1,0,MST))
            LEAVE      TCH,1
```

```
              SAVEVALUE  ACH-,1
              SAVEVALUE  NCA+,1
              TERMINATE  1

NCAC          SAVEVALUE  NCA+,1
              SAVEVALUE  ACH+,1
              ENTER      TCH,1
              ADVANCE
(EXPONENTIAL(1,0,MST))
              LEAVE      TCH,1
              SAVEVALUE  ACH-,1
              TERMINATE  1

HO            TEST GE X$ACH,100,HOAC
HODROP        SAVEVALUE  HOB+,1
              TERMINATE  1

HOAC          SAVEVALUE  ACH+,1
              SAVEVALUE  HOA+,1
              ENTER      TCH,1
              ADVANCE
(EXPONENTIAL(1,0,MST))
              LEAVE      TCH,1
              SAVEVALUE  ACH-,1
              TERMINATE  1
```

1.6 Guard Channel Scheme with Handoff and New Call Queuing (GCS_HOQ_NCQ)

This scheme is a combination of GCS_HOQ and GCS_NCQ. In this scheme, same channel-sharing method is used as in GCS, except that queuing of both handoff and new calls is allowed if necessary. When a channel is released in a cell, it is assigned to the next handoff call attempt waiting in the queue. If there is no handoff waiting in the queue, the channel is assigned to the next new call waiting in the queue (if any). The queuing of handoff calls is performed in the same manner as in GCS_HOQ and queuing of new calls is performed in the same manner as in GCS_NCQ. Flowchart of the simulation model is given in figure 8. In the flowchart, C represents total number of channels, Ca represents number of already allocated channels and C_h represents number of channels reserved for handoff calls.

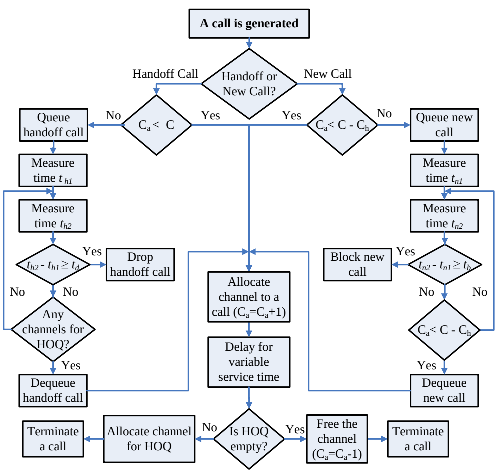

Figure 8: Simulation model of GCS_HOQ_NCQ scheme.

Simulation program of GCS_HOQ_NCQ scheme:

```
IAINT         EQU 1
MST           EQU 180
HQINT         EQU 20
NCINT         EQU 20

              TCH STORAGE 100
              GENERATE
(EXPONENTIAL(1,0,IAINT))
              TRANSFER   .5,NC,HO
```

```
NC         TEST GE X$ACH,80,NCAC
           QUEUE Newcall
           MARK
NCISCHAV   ADVANCE 0.1
           TEST GE
X$ACH,80,NCCHAV
           TEST GE
M1,NCINT,NCISCHAV
           DEPART Newcall
NCBLCK     SAVEVALUE  NCB+,1
           TERMINATE  1

NCCHAV     SAVEVALUE  ACH+,1
           ENTER     TCH,1
           DEPART Newcall
           ADVANCE
(EXPONENTIAL(1,0,MST))
           LEAVE     TCH,1
           TEST GE X$QH,1,NCNOQH
           SAVEVALUE  ACHQH+,1

           SAVEVALUE  QH-,1
           TERMINATE  1

NCAC       SAVEVALUE  ACH+,1
           ENTER     TCH,1
           ADVANCE
(EXPONENTIAL(1,0,MST))
           LEAVE     TCH,1
           TEST GE X$QH,1,NCNOQH
           SAVEVALUE  ACHQH+,1

           SAVEVALUE  QH-,1
           TERMINATE  1

NCNOQH     SAVEVALUE  ACH-,1
           TERMINATE  1

HO         TEST GE
X$ACH,100,HOACPT
           QUEUE Handoff
           MARK
           SAVEVALUE  QH+,1

HOISCHAV   ADVANCE 0.1
           TEST GE
X$ACHQH,1,HONOCHAV
HOCHAV     SAVEVALUE  ACHQH-,1

           ENTER     TCH,1
           DEPART Handoff
           ADVANCE
(EXPONENTIAL(1,0,MST))
           LEAVE     TCH,1
           TEST GE X$QH,1,HONOQH
           SAVEVALUE  ACHQH+,1

           SAVEVALUE  QH-,1
           TERMINATE  1


HONOCHAV TEST GE
M1,HQINT,HOISCHAV
           DEPART Handoff
           SAVEVALUE  QH-,1
HODROP     SAVEVALUE  HOB+,1
           TERMINATE  1

HOACPT     SAVEVALUE  ACH+,1
           SAVEVALUE  HOA+,1
           ENTER     TCH,1
           ADVANCE
(EXPONENTIAL(1,0,MST))
           LEAVE     TCH,1
           TEST GE X$QH,1,HONOQH
           SAVEVALUE  ACHQH+,1

           SAVEVALUE  QH-,1
           TERMINATE  1

HONOQH     SAVEVALUE  ACH-,1
           TERMINATE  1
```

2. Conclusion

In this study, GPSS was used in order to model some of the popular Call Admission Control schemes for cellular wireless networks. The following schemes dealing were modelled: Fully Shared Scheme (FSS), Fully Shared Scheme with Handoff Queuing (FSS_HOQ), Fully Shared Scheme with Handoff and New Call Queuing (FSS_HOQ_NCQ), Guard Channel Scheme (GCS), Guard Channel Scheme with Handoff Queuing (GCS_HOQ), Guard Channel Scheme with New Call Queuing (GCS_NCQ) and Guard Channel Scheme with Handoff and New Call Queuing (GCS_HOQ_NCQ).

This paper will be useful for academia interested in modelling of CAC schemes using GPSS.

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