AN INTELLIGENT AGENT FOR RADIO RESOURCE MANAGEMENT IN (W-CDMA) NETWORKS, ANALYTICAL AND COMPUTATIONAL SCALING.

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Abstract

Third generation mobile systems are the technology that will bring the new broadband services to the mobile user. However, providing flexible, higher bandwidth services in a mobile environment leads to increased complexity in resource control and resource management. That is because of the variable bandwidth requirements of the potential applications. Such complexity requires the use of sophisticated control and management techniques. Intelligent Agents (IA's) are seen as the most suitable candidates for the task. Intelligent agents have been used in many areas from workflow management to trading on the Internet[Soamsiri 2005]. The issue of using Intelligent Agent system to control the 3G resources is being addressed and developed in the EU IST project called 'SHUFFLE' .This project describes the key concepts and architecture of the 3G resource management in the SHUFFLE project, using Multi-agent systems. The architecture of the existing resource management, using a three-layer marketplace where radio bandwidth is being traded, is explored, together with the specifications for each party involved in the trade. A user Agent (UA) acts on behalf of the customer. The service provider is represented by a group of agents that consists of the Service Provider Agent (SPA), the Service Provider Negotiation Agent (SPNA), and the Service Provider Resource Agent (SPRA). The network provider is represented by the Network Provider Agent (NPA), the Network Provider Negotiation Agent (NPNA), and the Network Provider Resource Agent (NPRA). In each group, each agent takes care of different aspects and performs different tasks, but acts toward the shared goal. This research discussed how the project developed on top of the existing SHUFFLE architecture, a new set of agents that make use of various concepts focused on providing end-users with the best possible QoS[Oodan and etal 1977]. This project provides the foundation for the SLA concept and agent reputation system that had not been implemented in SHUFFLE before. The SLA monitoring and evaluation, which is implemented in this project only in the network provider, can also be implemented with some minor changes into the service provider agent and the user agent in order to provide a complete QoS control throughout the entire system.

The work of this research project proposes the application of intelligent agents in SLA-based control in resource management, especially call admission control and handoff control in the case at high loads occurs. The work demonstrates the ability of intelligent agents in improving and maintaining the quality of service to meet the required SLA.

Also this work propose a new method that use memory technique to store the calls before accept / reject the calls from the system for a few seconds dependent on QoS and explores this period to study the system environment and implement the most suitable policy that is predicted to the system.

A particularly novel aspect of this work is the use of learning (here Case Based Reasoning) to predict the control strategies to be imposed. As the system environment changes, the most suitable policy will be implemented. The system either proposes the solution by recalling from experience (if the event is similar to what has been previously solved) or recalculates the solution from its knowledge (if the event is new). With this approach, the system performance will be monitored at all times and a suitable policy can be immediately applied as the system environment changes, resulting in maintaining the system quality of service. Furthermore, we believe that this research project have produced a significant new research contributions. Those contributions can be summarized in the following results which have arisen out of our research investigation achieving the following:

- Maximum acceptable blocking rate for gold : 0.03.
- Maximum acceptable blocking rate for silver: 0.05.
- Maximum acceptable blocking rate for bronze: 0.08.
- Maximum acceptable dropping rate for gold : 0.02.
- Maximum acceptable dropping rate for silver: 0.04.
- Maximum acceptable dropping rate for bronze: 0.06.

I-Research Motivation

In most 2G situations, each call has the same bandwidth demand so it is merely a matter of checking whether a spare timeslot is available. The system capacity, or the number of users, is governed by the number of timeslots available. Therefore, the decision whether to admit a call request is concerned only with the timeslot (or resource) availability. With Wideband Code Division Multiple Access (W-CDMA) being used for the third generation cellular networks (3G networks), the system capacity becomes more flexible, since all users share the same spectrum allocation and use codes to identify themselves from others[Cuthbert and etal 2001] [Ojanpera and etal 1998]. Hence the whole bandwidth can be reused in every cell and the system capacity is limited by the total interference that occurs from other users (in the case of the network being uplink - capacity limited), or other base stations (in the case of the network being downlink - capacity limited) and the background noise. Hence, providing the flexible, higher bandwidth services, and maintaining the best system capacity leads to more complexity in Radio Resource Management (RRM) [Ahmad Alsolaim 2002] [Saussy 2002].

Playing a crucial part in 3G networks, RRM controls the system capacity and affects the management of service quality[Wisely 2002 Yue Chen 2003][Tero and etal 2000]. Congestion is a major event that leads to a deterioration of system Quality of Service (QoS). When congestion occurs, action(s) needs to be taken as part of load control algorithm. The motivation of this research comes from the requirement to introduce efficient RRM by offering Service Level Agreement (SLA) based policies to maintain the QoS as guaranteed in the SLA. [Cuthbert and etal 2001]

II-Research Scope

To the best of our knowledge, our work is the first that apply artificial intelligent for RRM to maintain the QoS as guaranteed in the SLA. To investigate this, a detailed model for the system including algorithms supported by computer simulation had to be created, that allowed the system to be monitored to recognize the problem pattern (call request blocking or handoff blocking), that will make the system operation out of SLA, to get the RRM to execute approximate action.

III-Contributions

The main contributions in this work are:

- An in-depth study of RRM that is power control, call admission control, handover control, and congestion control.
- A detailed modeling of the system behavior that implements intelligent agents and the Case-Based Reasoning (CBR) learning approach.
- A CBR implementation in RRM that recognizes congestion and takes action to manage the load on the network.
- A CBR implementation in RRM that take actions to manage handoff blocking on the network when the users traveling to a congestion area.
- A novel application of the CBR approach to allow fast convergence of the agent policies and the calculation method used in the cases where an unfamiliar situation occurs.

It should be noted that while the background concept of the agent architecture used in this work came from the IST project IST-1999-11014 (SHUFFLE) that was finished in 2002. The work on applying intelligent agents in SLA-based control came from [Soamsiri 2005] that was finished in 2005, the work on applying intelligent agents in RRM and using learning techniques and artificial intelligent algorithms as described here is wholly that of the student's project and was not part of that projects.

IV-Mechanism of applying intelligent agent on the communication system

first the data is collected from the system and the percentage of blocking rate and dropping rate will be calculated, the data will be compared with SLA. If the SLA is breached the system identify the type at problem either call request blocking or handoff blocking[Aamodt and etal 1994] [FPLMTS.REVAL 2000]
In the case of call request blocking the system will collect data from system including the position at congestion around the cell and throughput of system and

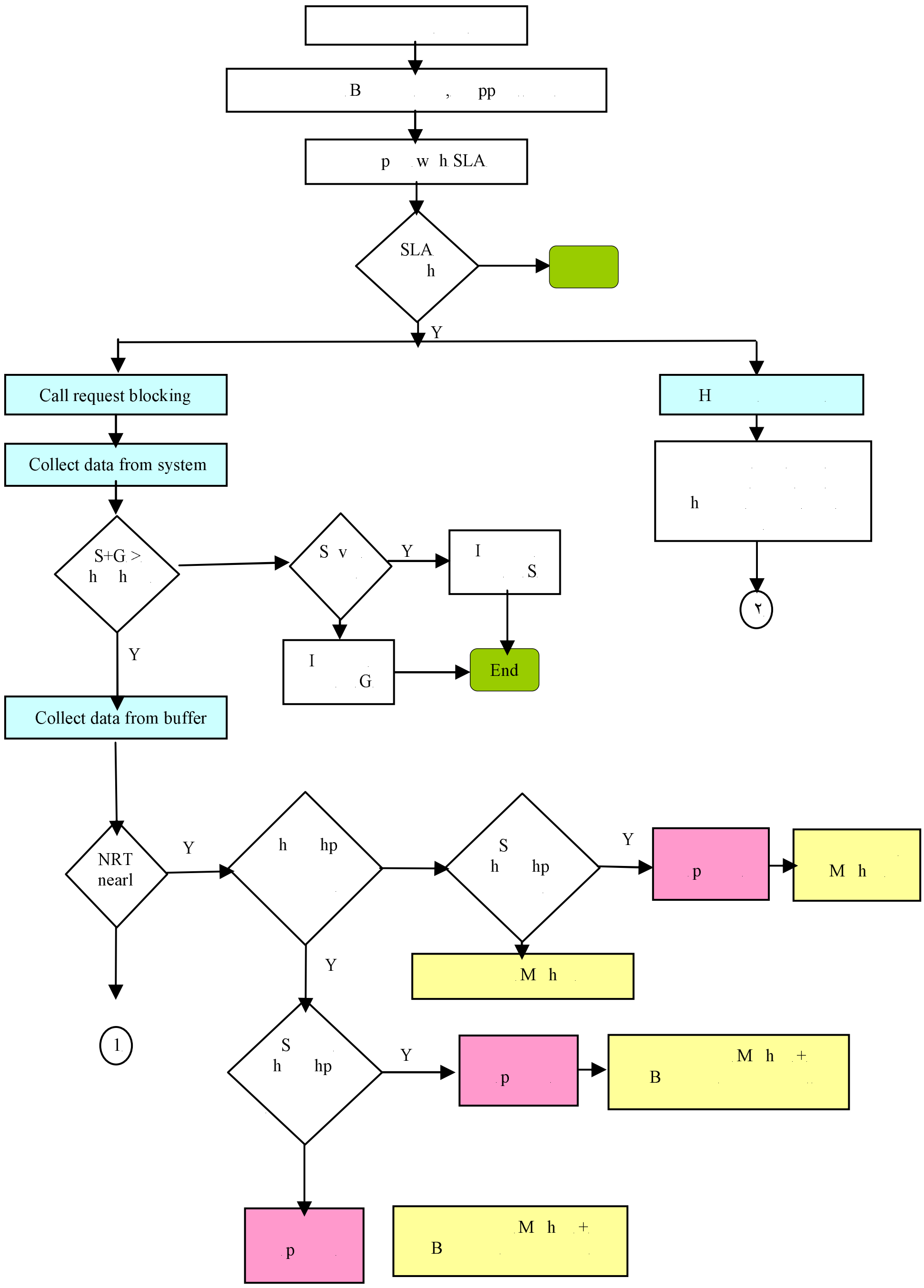
will compare the system throughput with threshold throughput[Aamodt and etal 1994].

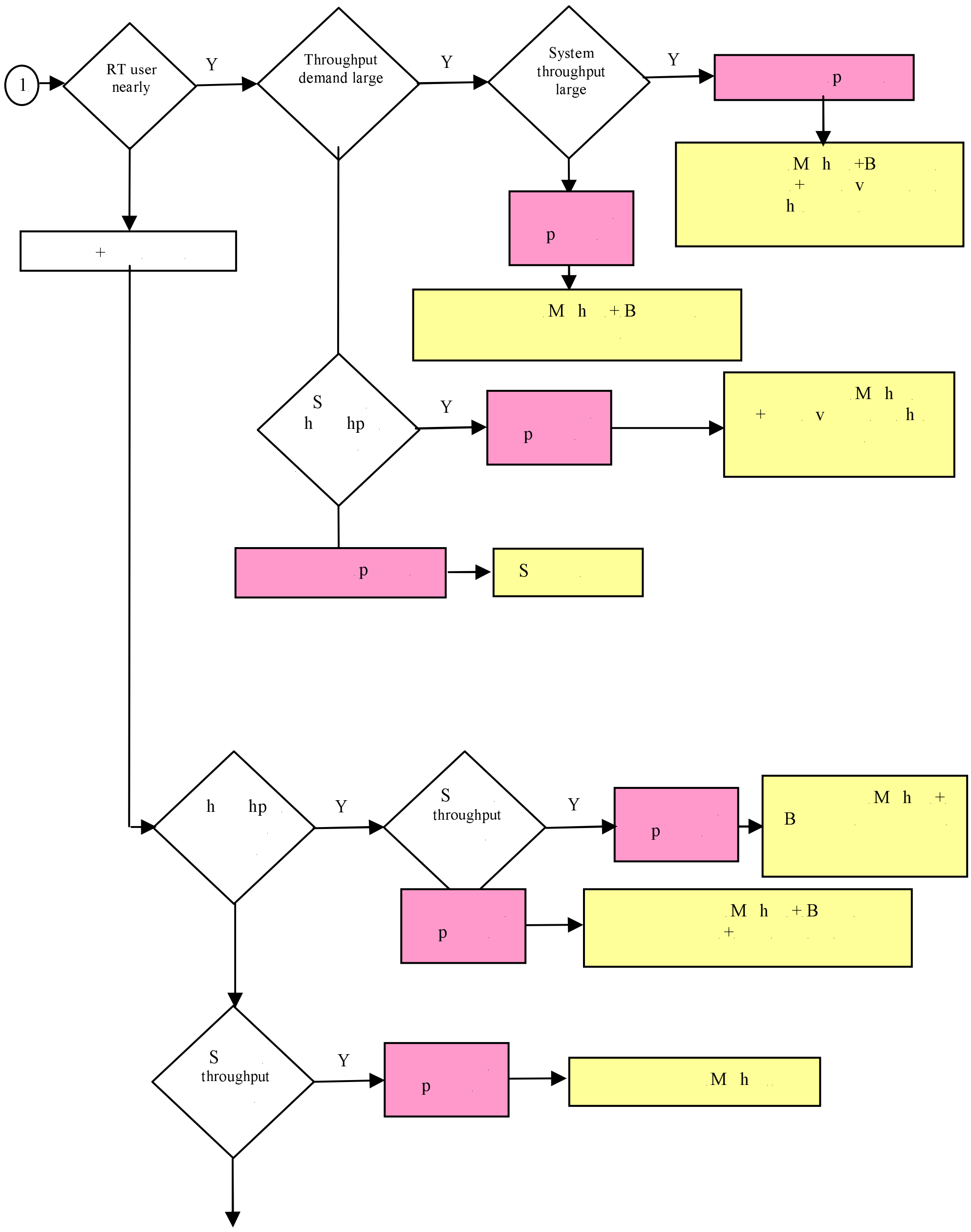
Data were collected from buffer content such as type of service demand, all throughput demand, priority users and other data. There are three probabilities:

First probability all users in the buffer Non Real time users nearly and **second** probability that all users are Real time nearly and third probability that at users are RT and NRT.

According to each type the calculations were made and the suitable policy was applied as appear in the flowchart below.

In the case of handoff blocking the system will collect data such as data about cell target or, in other words, cell that the user will travel to it, and type of services for the traveling users and throughput demand and throughput offered and other information that is needed. The flowchart below explains in details all the steps in the handling process for the calls that is in handoff state and it froms handoff problem[Holma and etal 2000] [http://www.gsmworld.com].


SLA
Y
Call request blocking
Collect data from system
S+G >
Y
Collect data from buffer
End
NRT
Y
1
M h
M h +
B
End


1
RT user nearly
Y
Throughput demand large
Y
System throughput large
Y
p
M h +B
+ v
h
p
M h + B
+
S
h hp
Y
p
M h
+ v h
p
S
h hp
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S
throughput
Y
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M h +
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S
throughput
Y
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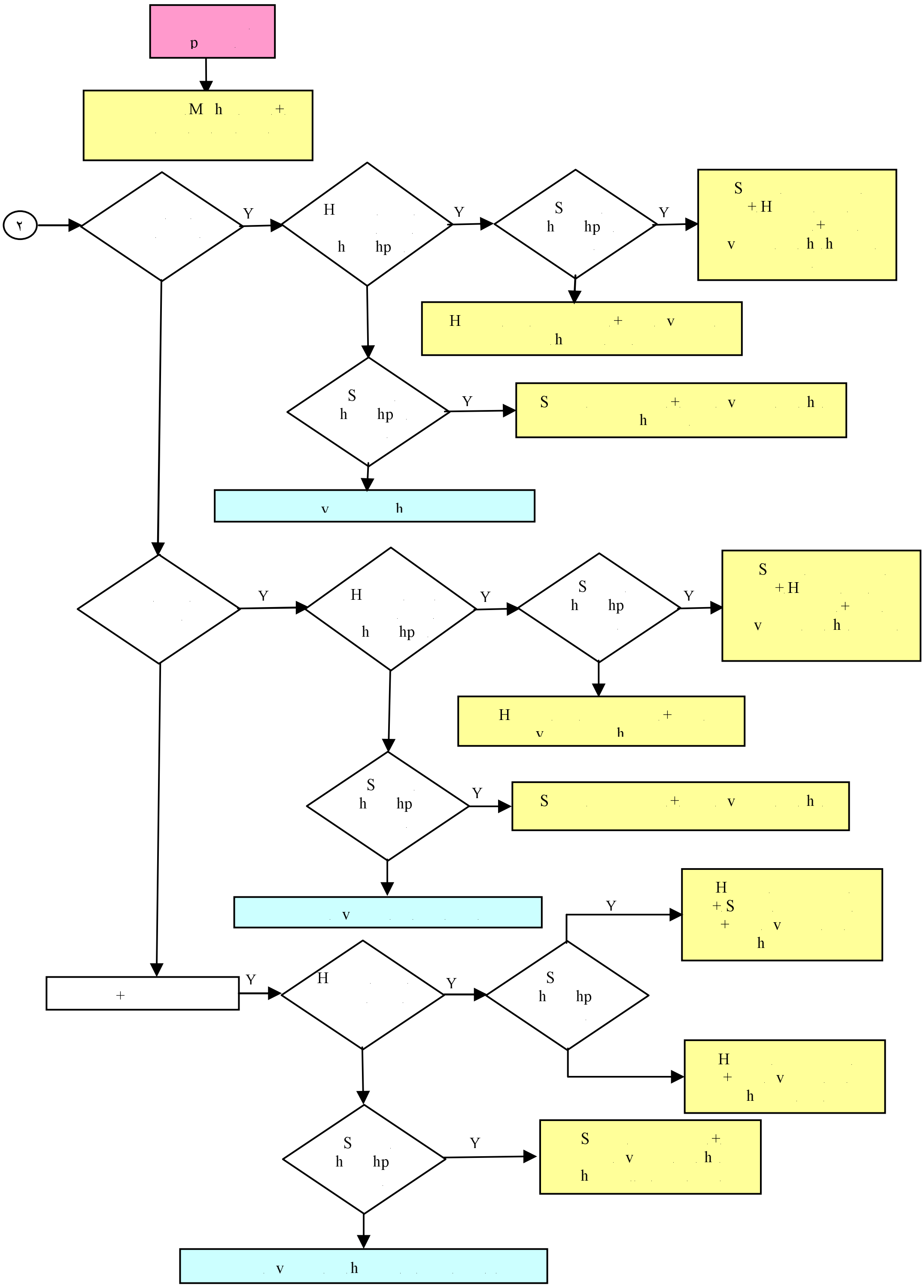
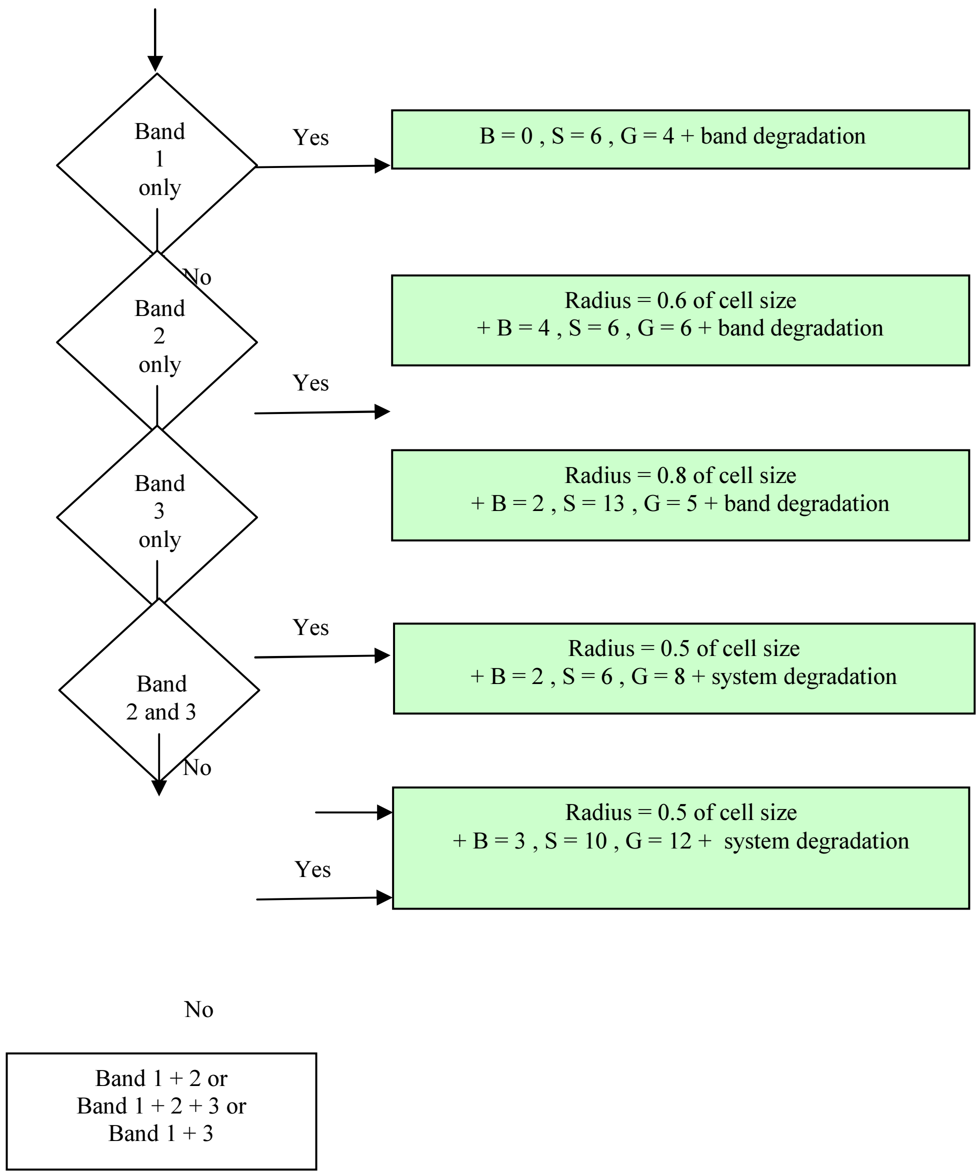


Calculation Method



V-Simulation Results

The results below represent some of the results which we obtained in our project. The call blocking rate for all customer classes increases when the traffic load increases as there is no change in policy as shown in figure 1. The blocking rate for gold customer exceeds the SLA constraint. From the start, the call buffering time (or call setup time) for all classes of customer and all types of services has been set to zero to give immediate accept or reject decisions for the system.

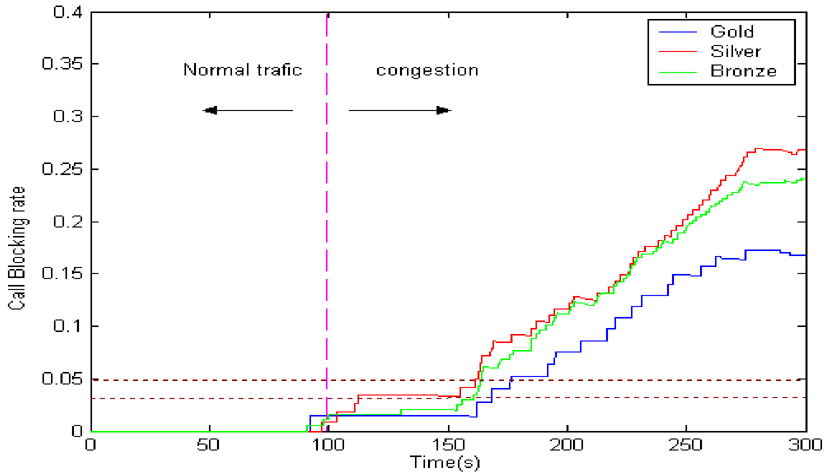


Figure (1) The conventional system that does not change the policy

1. Generating Cases

In this part, the generation of cases for the CBR model will be given. There are two main scenarios tested here: random overload cases and hotspot cases. Several methods have been taken into account and the configurations used to recover from congestion have been chosen based on experiments. Therefore, the solution for each case is achieved by selecting the solution that provides the best result.

1.1 Random Overload Cases

In this part, the simulation repeated the previous work, the simulation result of the call blocking rate over simulation time as the traffic load increases in a conventional system that does not change the policy as shown in figure1. The effect of changing the reactive layer policy to the chosen one is shown in figure 2. The new policy has been applied to the reactive layer as soon as the system recognizes congestion.

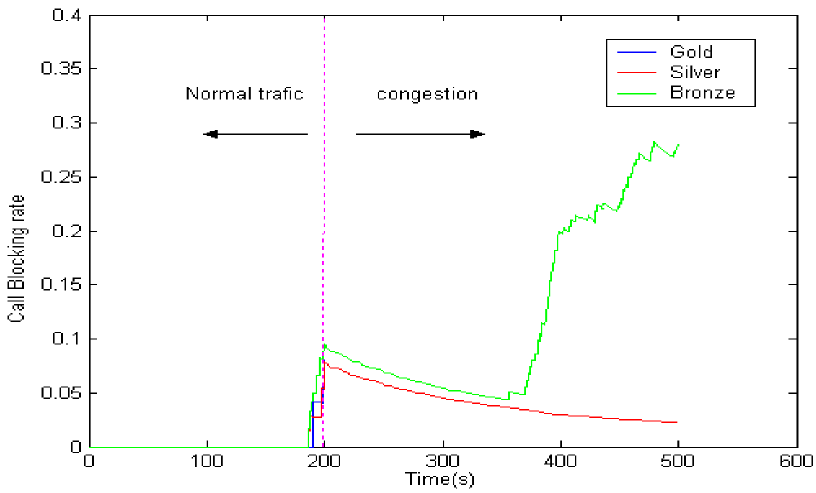


Figure (2) The new policy has been applied to the reactive layer

The implementation here again uses a buffer mechanism to give a short buffering time to call requests that cannot be served immediately, especially for the higher priority customers. The buffering time is configurable. It can be seen from the results that this application keeps the call blocking rate for gold and/or silver customers within the SLA bounds.

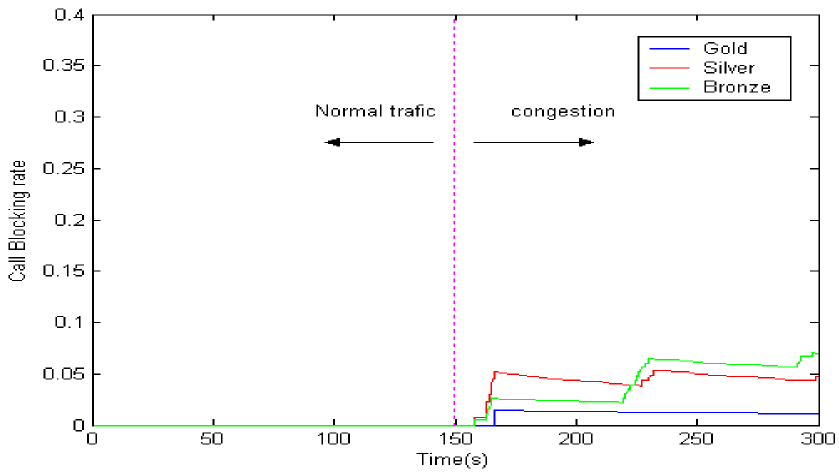
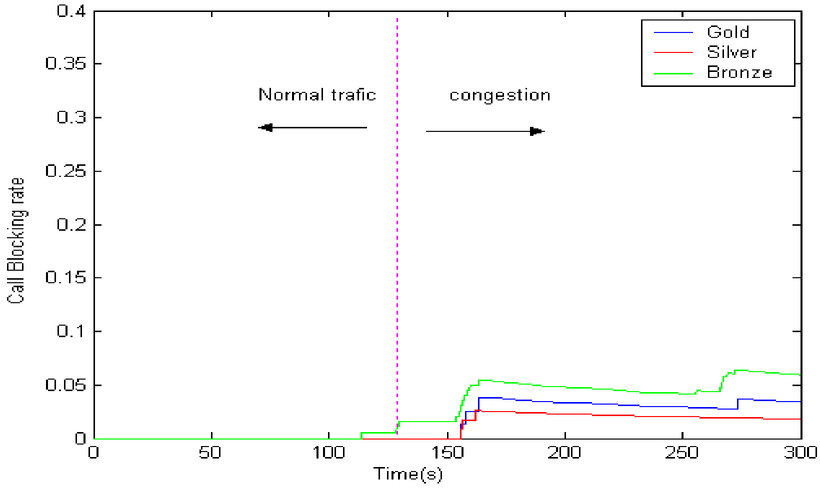


Figure (3) The call blocking rate for gold and/or silver customers keeps within the SLA bounds

The traffic reaches overload when the accumulative call blocking rate for gold customers exceeds the limit. At that point silver customers is still in an acceptable range as shown in figure 3. In this case the chosen policy gives the highest buffering time to gold (6s) and lower value for silver (4s) and for bronze still at zero. It can be

seen that the system detected the overload situation at the point where the traffic load increases and the new policy is applied. As the new policy gives priority to gold, the call blocking rate for gold customer is maintained within an acceptable range at the expense of both silver and bronze.
The long-term value for gold customers has been met comfortably as shown in figure 4, but that for silver is at the limit. When congestion occurs, silver customers have to be given priority in order that their long-term blocking is not exceeded, but gold customers can be allowed to have worse service since there is still "slack" in their SLA. The SLA monitoring here is looking at the long-term blocking. It has detected that silver needs priority and has applied that priority.



Figure(4) The SLA monitoring here is looking at the long-term blocking, has detected that silver needs priority and has applied that priority

In this case, the buffering times for gold, silver and bronze customer have been set as 6s, 8s and 4s respectively. According to the implementation of priority buffering, gold customer are always placed in the front of the queue. Therefore, in order for bronze to also be maintained, the highest buffering time was given to bronze and a smaller amount to silver, so maintaining silver customers within acceptable range. These results show the flexibility of the control system, which assigns different policies to different scenarios and also shows that the highest priority traffic can also be a sacrifice in order to maintain a long-term SLA for customers who would normally have lower priority. In fact any SLA that can be evaluated numerically can be used as the basis for controlling the policy, the system is that flexible.

V-1 Hotspot Cases

In this section the solution mechanism will be applied dependent on *memory buffer throughput, system throughput, and the congestion band in the cell.*
For studies propose we recognize three type of users in the:

- The system contains in some instant period more than 70% RT users.

- The system contains in some instant period more than 70% NRT users.
- The system contains in some instant period RT and NRT users in approximately equal number of users.

And three type of users memory buffer:

- the buffer contain in some instant period more than 70% RT users.
- the buffer contain in some instant period more than 70% NRT users.
- the buffer contain in some instant period RT and NRT users in approximately equal number of users.

In all case as the congestion occurs in the hotspot area of the hotspot cell, the call blocking rate for all classes of customer increases. From the generation of cases for the case library shown previously, the CBR model was built up. To check that it operates correctly, the simulation was run with the same conditions as used to generate the case to ensure it does match exactly.

We will consider all possible type of congestion and examine the network to take the most suitable solution for each case.

V-2Hotspot Cases Simulation and Analysis

First experiment:

 # The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

 # System parameters that are collected in the monitoring process before apply the solution:

* The system contains more than 70% NRT users**,** *system throughput large.*

* the buffer contain more than 70% NRT users, *throughput demand large.*

Congestion pattern is in: first band (distance less than 350m).

 # The results (by graph**) that came from the SLA-based control system by implementing the CBR to propose the best solution:**

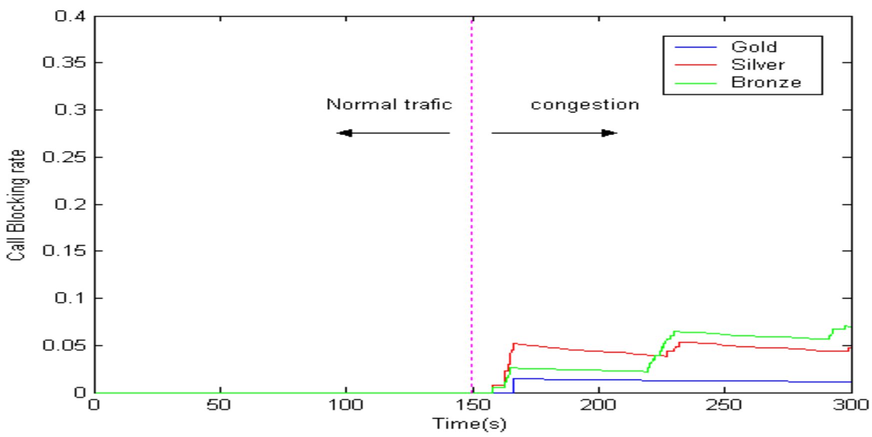


Figure (5) First experiment result

 # The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes:

First band degradation, buffering degradation and in this case, the buffering times for gold, silver and bronze customer have been set as 4s, 6s and 0s receptivity.

second experiment:

 # The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

 # System parameters that are collected in the monitoring process before apply the solution: * The system contains more than 70% NRT users**,** *system throughput large.*

* The buffer contains more than 70% NRT users*, throughput demand large.*

 # Congestion pattern is in: band two and three (distance more than 350m and less than 1000m).

The results (by graph**) that came from the SLA-based control system by implementing the CBR to propose the best solution:**

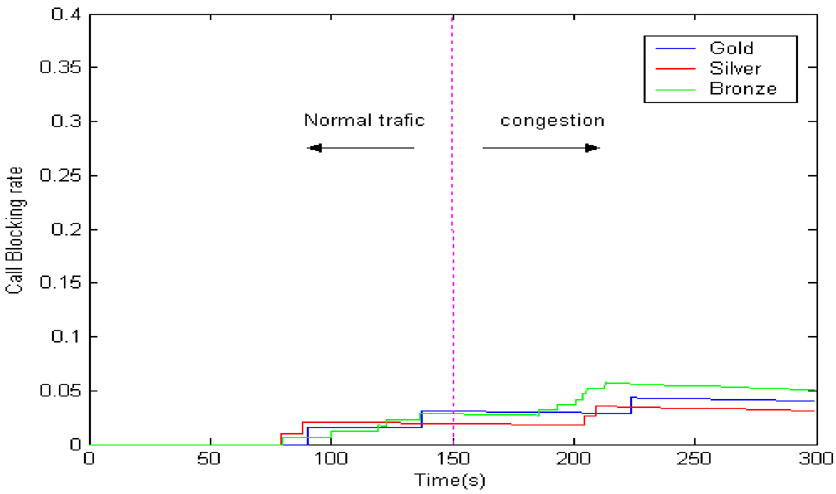


Figure (6) second experiment result

 # The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: System degradation, buffering degradation and In this case, the buffering times for gold, silver and bronze customer have been set as 8s, 6s and 2s respectively.

thired experiment:

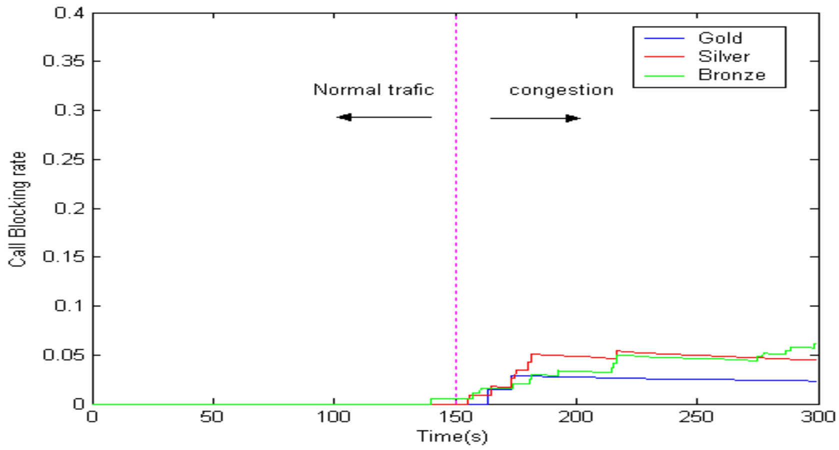
The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution: * The system contains more than 70% RT users**,** *system throughput large.*

* The buffer contains nearly RT users*, throughput demand small.*

Congestion pattern is in: whole system.

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**



Figure(7) Third experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: System degradation, NRT over load, cell radius shrinking to (0.8) of cell size and In this case, the buffering times for gold, silver and bronze customer have been set as 12s, 10s and 3s respectively.

experiment: 4th

The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution: * The system contains nearly RT users**,** *system throughput small* (voice).

* The buffer contains more than 70% RT users*, throughput demand large* (video**).**

Congestion pattern is in: third band (distance more than 700m).

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

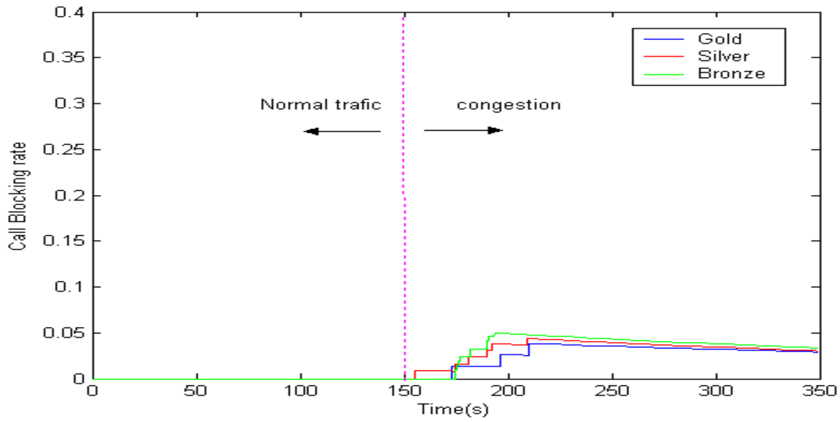


Figure (8)4th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: Buffering degradation, cell radius shrinking to (0.8) of cell size and In this case, the buffering times for gold, silver and bronze customer have been set as 13s, 9s and 6s respectively.

5th experiment :

The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains nearly RT users**,** *system throughput small* (voice).

* The buffer contains nearly RT users, *throughput demand small* (voice**).**

 # Congestion pattern is in: first band (distance less than 350m).

The results (by graph**) that came from the SLA-based control system by implementing the CBR to propose the best solution:**

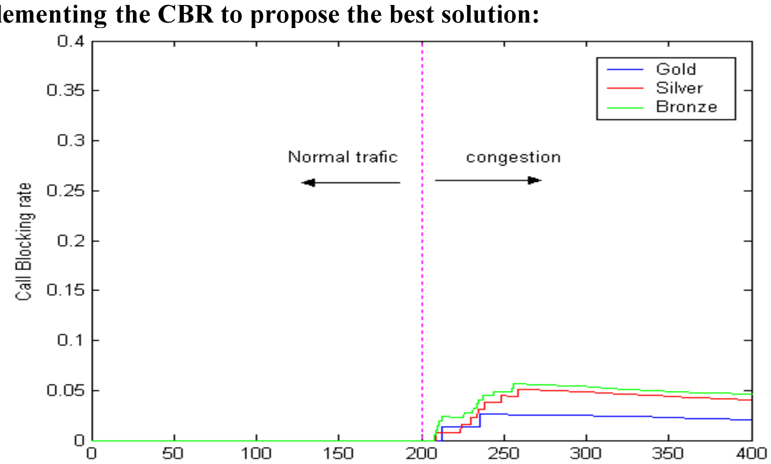


Figure (9) 5th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and its causes:
In this case only buffering mechanism used, the buffering times for gold, silver and bronze customer have been set as 10s, 8s and 5s receptivity.

6th experiment:

The problem detected by the monitoring process: SLA breached, where call blocking rate exceed maximum acceptable call blocking rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution: * The system contains RT & NRT users**,** *system throughput large.*

* The buffer contains RT & NRT users*, throughput demand large***.**

 # Congestion pattern is in: whole cell.

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

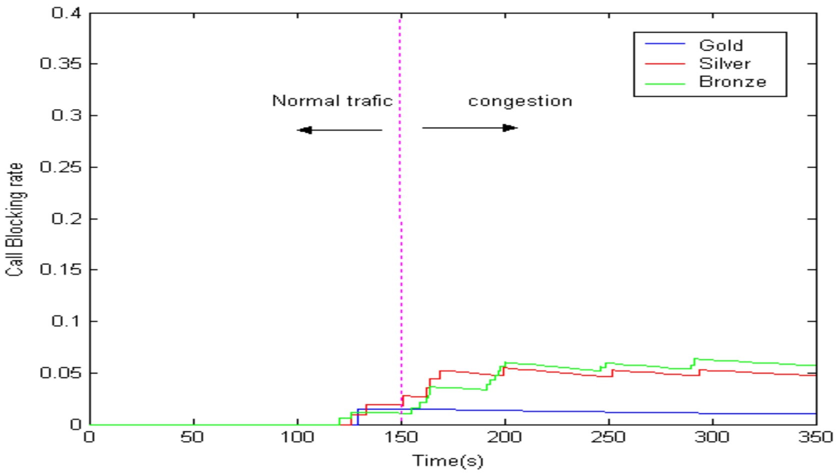


Figure (10) 6th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes:
System degradation, buffering degradation, cell radius shrinking to (0.8) of cell size and In this case, the buffering times for gold, silver and bronze customer have been set as 5s, 3s and 0s respectively.

V-3 Simulation of changing reactive layer policy for handoff control handling

For this part, the simulation result of the handoff call blocking rate (and therefore dropping) over simulation time increases in a conventional system that does not change the policy is shown in figure 8.17.

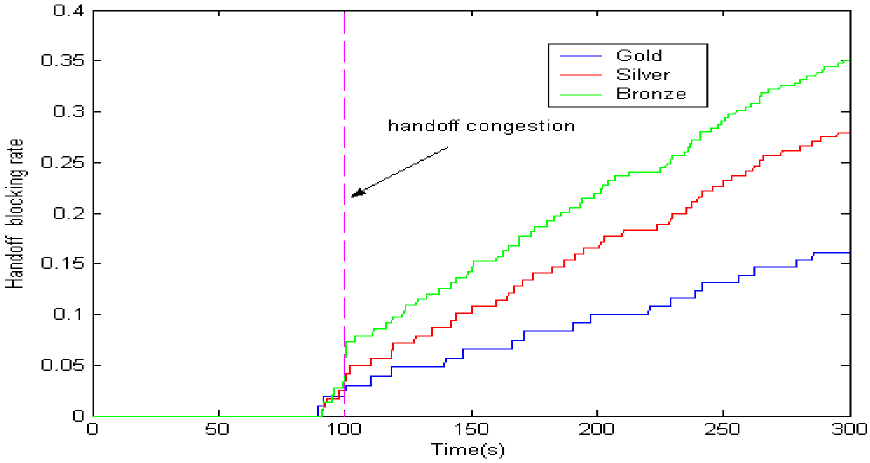


Figure (11) A conventional system that does not change the policy

Generating Cases

7th experiment:

 # The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

 # System parameters that are collected in the monitoring process before apply the solution:

* The system contains more than 70%NRT users**,** *system throughput large.*

* The users in state of handoff contains more than 70% NRT users, *users in state of Handoff demand large throughput.*

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

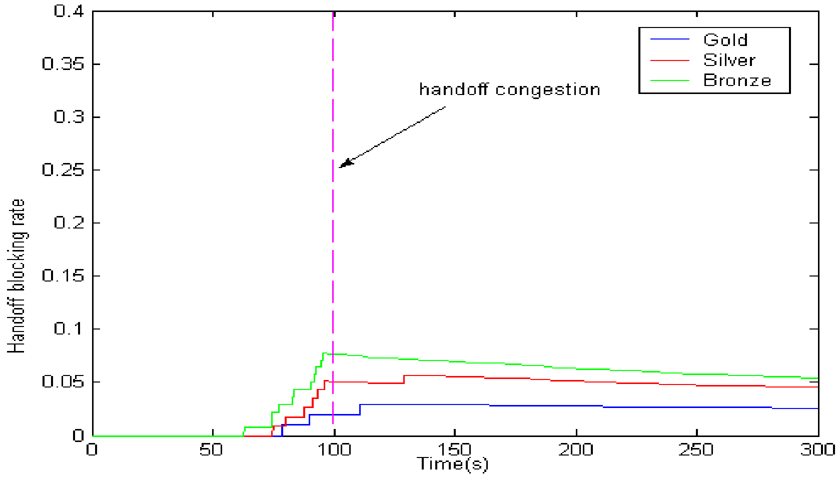


Figure (12) 7th experiment result

 # The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes:
System degradation + Handoff calls degradation +NRT overload for the handoff calls.

8th experiment:

The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains more than 70% NRT users**,** *system throughput large.*

* The users in state of Handoff contains NRT users, *users in state of handoff demand small throughpu*[Yue Chen 2003]*t.*

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

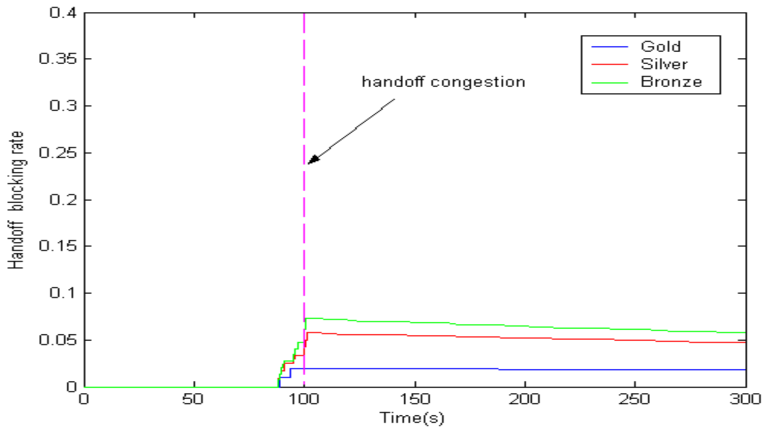


Figure (13) 8th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: System degradation + NRT overload for the handoff calls.

9th experiment:

The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains NRT&RT users**,** *system throughput large.*

* The users in state of Handoff contains NRT&RT users, *users in state of Handoff demand large throughpu*t.

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

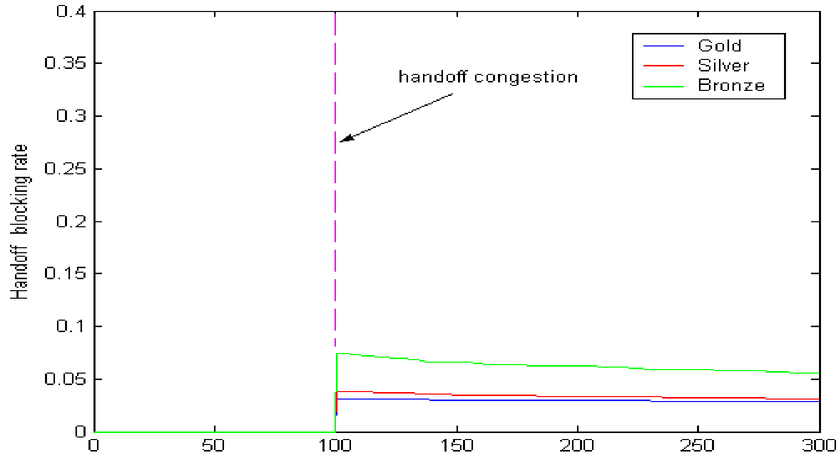


Figure (14) 9th experiment result

 # The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes:

Handoff degradation, System degradation and NRT overload for handoff calls.

10th experiment:

The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains NRT&RT users**,** *system throughput large.*

* The users in state of Handoff contains NRT&RT users, *users in state of Handoff demand small throughput.*

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

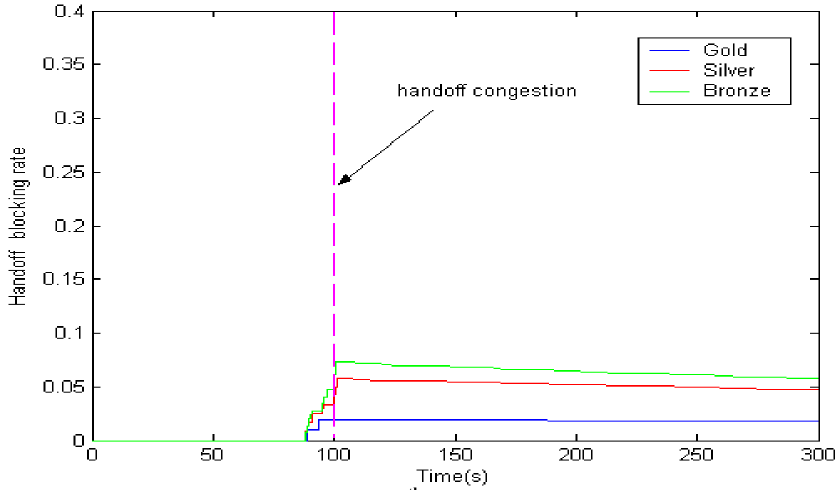


Figure (15) 10th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes:

System degradation as well as NRT overload for the handoff in large time.

11th experiment:

The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains more than 70%RT users**,** *system throughput large.*

* The users in state of handoff contains more than 70% RT users, *users in state of Handoff demand large throughput.*

The results (by graph) **that came from the SLA-based control system by implementing the CBR to propose the best solution:**

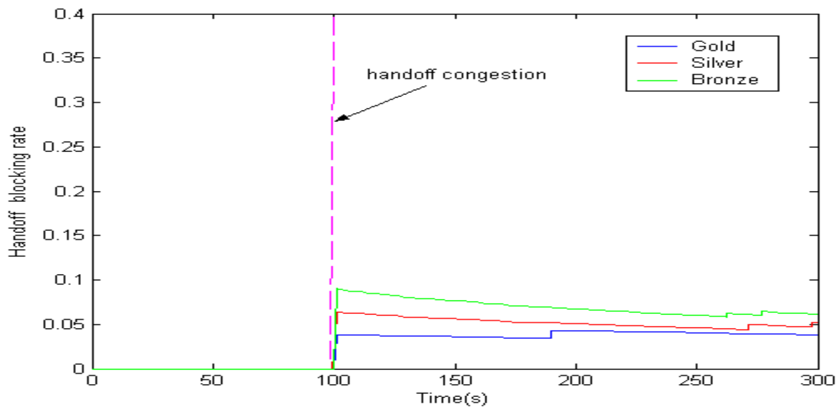


Figure (16) 11th experiment result

 # The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: System degradation+ Handoff call degradation as well as NRT overload for the system.

12th experiment:

The problem detected by the monitoring process: SLA breached, where call dropping rate causes by handoff call blocking exceed maximum acceptable call dropping rate as agreed in the interact.

System parameters that are collected in the monitoring process before apply the solution:

* The system contains more than 70% RT users**,** *system throughput large.*

* The users in state of handoff contains RT users, *users in state of Handoff demand small throughput*.

 # The results (by graph**) that came from the SLA-based control system by implementing the CBR to propose the best solution:**

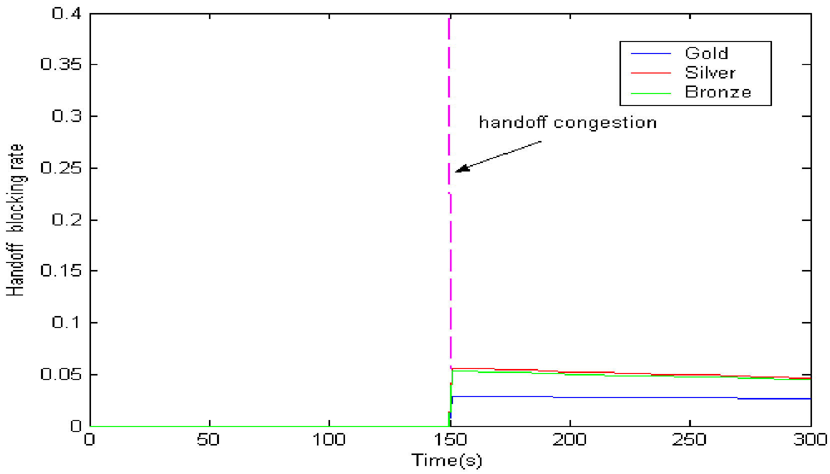


Figure (17) 12th experiment result

The most suitable policy chosen and applied into the system by CBR according to this type of congestion pattern and it's causes: System degradation as well as NRT overload for the system user.

VI-Conclusions

This project has described the background to the evolution of the cellular systems, mainly the evolution from the 2nd generation (GSM) toward the 3rd generation wireless systems (UMTS). Given the higher demand for bandwidth and the complexity of the new applications that UMTS will support, clearly a flexible and dynamic management of radio resources will be needed. The approach taken by SHUFFLE is to make use of a Multi-agent System, which is already proved effective in many telecommunication areas.

The concept of dynamic and flexible management of radio resource in SHUFFLE was discussed, explaining how and why the Multi-agent should and can be used.

The architecture of the existing resource management using a three-layer marketplace was explained, together with the specifications of each party involved in the trade. Ideally, the three players: the customer, the service provider, and the network provider, that are involved in the UMTS business model should be represented by three agents or three groups of agents. The User Agent (UA), acting on behalf of the customer, generates demand for the system. The service provider represented by a group of agents consists of the Service Provider Agent (SPA), the Service Provider Negotiation Agent (SPNA), and the Service Provider Resource Agent (SPRA). The network provider is represented by the Network Provider Agent (NPA), the Network Provider Negotiation Agent (NPNA), and the Network Provider Resource Agent (NPRA). In each group, each agent takes care of different aspects and performs different tasks, but acts toward the shared goal.

In this project, the concept of user QoS is discussed together with the framework of the QoS control that can be used to monitor and control radio resource allocation in 3G. The concepts of Service Level Agreement and reputation model were discussed.

The results of the simulation demonstrate how a multi-agent system could benefit the resource management in the 3G systems. By introducing the updated Network Provider Resource Agent (NPRA), customer experiences lower blocking rate. The concepts of SLA and reputation model were put in to practice, and provided an effective means for QoS management especially for the service provider.

Moreover, the NPRA demonstrates the ability to differentiate customers with different service classes, giving them different priorities at times when resources are scarce. This project therefore developed, on top of the existing SHUFFLE architecture, a new set of agents that make use of various concepts focused on providing end-users with the best possible QoS. At the same time, the agents still maintain their goal of providing a flexible and dynamic resource management for the upcoming 3G systems. This project provides the foundations for the SLA concept and agent reputation system that have not been implemented before in SHUFFLE. The SLA monitoring and evaluation, which is currently implemented only in the network provider, can also be implemented with some minor changes into the service provider agent and the user agent, in order to provide complete QoS control throughout the entire system. This project also provides a sequence of simulation results starting from the initial stage of the investigation on the impact of changing the reactive layer policy to overcome the system congestion environment and handling handoff blocking call. Results from the study of implementing the CBR as part of the agent system to propose the best solution for each congestion pattern were presented.

Results were given for:

- The results from the case generation process, which showed the benefit of using the proposed method in recovering different congestion patterns. The result from the same scenario used to populate the case library was also given to ensure that the system can immediately propose the right policy to the congestion pattern.
- The results from simulation under similar hotspot patterns, which showed the flexibility and learning ability of the system.

- The results from simulation under handoff problems, which showed that the system was able to learn from experience and adapt the knowledge to give the right policy to recover the system to the ordinary situation.

Finally, this work has shown that there is value in using Case Based Reasoning to manage the reactive layer policies in an agent-based RRM system. Because the target of the management system can be expressed in any form the system is extremely flexible. The results here have been applied to both call blocking and handoff blocking.

IIIX- Further Work

- Generalize our results to make solutions for RRM problems in a beyond 3G framework, where several RATs are jointly managed.
- Evaluate the performance of CBR in more complex scenarios such as faster moving mobiles where handover call dropping may be more of an issue.
- Expanding this project by including the agents in the negotiation plane to investigate how interaction between agents affects the underlying concept.
- Implement the SLA monitoring and evaluation into the service provider agent and the user agent, in order to provide complete QoS control throughout the entire system.

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