

Performance Evaluation of a Fuzzy-based Integrated CAC and Handover System for Cellular Networks

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Abstract—Several schemes have been proposed for CAC and handover in wireless cellular networks. However, during the complexity of CAC and handover in wireless environment, many simplified models and assumptions are made. Also, the CAC and handover algorithms operating in real time have to make decisions without the luxury of repeated uncorrelated measurements or the future signal strength information. It should be noted that some of CAC and handover criteria information can be inherently imprecise, or the precise information is difficult to obtain. For this reason, we propose a Fuzzy Logic (FL) based approach for CAC and handover for wireless cellular networks (called FICHS), which can operate with imprecision data and non-linear functions with arbitrary complexity. To evaluate the performance of FICHS we consider CAC with priority and enforced handover. We show that FICHS has a good behavior.

Keywords- Fuzzy; CAC; Handover; Cellular Networks; Fuzzy Logic.

I. INTRODUCTION

During the last few years wireless multimedia networks have been a very active research area [1], [2]. The QoS support for future wireless networks is a very important problem. Call Admission Control (CAC) and handover strategies are needed for providing the required QoS [3]–[6].

Several schemes have been proposed for CAC in wireless cellular networks. However, during the complexity of CAC in wireless environment, many simplified models and

assumptions are made. Some schemes consider that each mobile node will make hand-over to neighboring cells with equal probability, which may be not accurate in general.

In [7], the authors propose a simple and robust fuzzy-based algorithm to predict the Cell Loss Ratio (CLR) in large-sized systems based on both a small amount of information from small-sized systems, and the asymptotic behavior for very large systems. Unlike the model-based approaches, this approximation avoids the problem of assuming any traffic parameters or arrival process. This algorithm is used with real-time traffic measurement and provide an effective measurement-based CAC framework for ATM networks.

Since the traditional guard channel policy is not optimal for a hard constrained handoff dropping probability, new CAC algorithms have been studied in [8]. The authors discuss simplifications to the original scheme and enhance the modified scheme by considering the difference of mobility support requirement between high and low mobility users. The simulation results show that the enhanced scheme gives better performance.

CAC plays a significant role in providing the desired QoS in wireless networks. In [9], the analytical results for some performance metrics such as call blocking probabilities are obtained under some specific assumptions. It is observed, that due to the mobility, some assumptions may not be valid, which is the case when the average values of channel holding

times for new calls and handoff calls are not equal.

In [10], the authors provide a CAC policy that is designed to make efficient use of the limited wireless channel. This scheme takes advantage of the diverse traffic characteristics in order to admit flows based on the requested traffic parameters. Simulation results are included to verify the validity of this approach and its importance in future wireless communication.

Handover is a key feature of mobile communication networks which mainly resides in the BS subsystem (BSS). Therefore the BSS design is heavily affected by handover process and vice versa. In [11], the handover related performance evaluation issues are outlined. Different types of handover are taken into account. Also the design methodology of the BS system architecture is discussed.

A novel class of direction biased handoff algorithms are proposed for improving the handoff performance in urban microcells [12]. Multi-cell urban microcell handoff properties are derived for a cell layout with BSs at every other intersection. The direction biased handoff algorithms are shown to improve cell membership properties and handoff performance by lowering the mean number of handoffs while simultaneously reducing the handoff delay. A direction estimation technique based on the signal strength history is shown to provide improved handoff performance, especially for line of sight handoffs.

In [13] is evaluated the performance of handoff schemes in microcellular Personal Communication Systems (PCS) which cater to both pedestrian and vehicular users. Various performance parameters, including blocking of new calls, channel utilization, handoff blocking and call termination probabilities for each user type are evaluated. Different queuing disciplines for handoff calls and their impact on system performance are studied. It is also studied the tradeoff in handoff blocking and call termination probabilities between user types as the handoff traffic carried by the system from each user type is varied.

The author in [14] presents an overview of published work on handover performance and control and discusses current trends in handover research. Investigations that are applicable to a single tier of cells are discussed. This research is focused on macrocells, but includes a brief discussion on how things change as cell sizes shrink.

Recently, many investigations have addressed handover algorithms for cellular communication systems. However, it is essentially complex to make handover decision considering multiple criteria. Sometimes, the trade-off of some criteria should be considered. Therefore, heuristic approaches based on Neural Networks (NN), Genetic Algorithms (GA) and Fuzzy Logic (FL) can prove to be efficient for wireless networks [15], [16].

In our previous work, in order to deal with CAC in wireless cellular networks, we proposed a CAC scheme based on FL [17], [18]. We implemented and evaluated the

proposed system by comparing its performance with Shadow Cluster Concept (SCC) [19].

In [20], a multi-criteria handover algorithm for next generation tactical communication systems is introduced. The handover metrics are: RSS from current and candidate base transceivers, ratio of used soft capacity to the total soft capacity of base transceivers, the relative directions and speeds of the base transceivers and the mobile node.

In [21], a handover algorithm is proposed to support vertical handover between heterogeneous networks. This is achieved by incorporating the mobile IP principles in combination with FL concepts utilizing different handover parameters.

In this paper, we evaluate the performance of an integrated system for CAC and handover in wireless cellular networks called FICHS. The structure of this paper is as follows. In Section II, we present CAC. In Section III we introduce the handover decision problem. In Section IV, we explain our system. In Section V, we discuss the simulation results. Finally, some conclusions are given in Section VI.

II. CAC

CAC is a provisioning strategy that limits the number of connections into the network in order to reduce the network congestion and call dropping. CAC is not a problem that is unique to wireless networks. It is applicable to almost every type of networks, but in cellular wireless networks due to users mobility the CAC becomes much more complicated.

While in wired networks the resources are reserved for the call at set-up time and are not changed after that, in cellular wireless networks when the mobile node moves from one cell to another one, the bandwidth must be requested in the new cell. During this process, the call may not be able to get a channel in the new cell to continue its service due to the limited resource in wireless networks, which will lead to the call dropping. Thus, the new and handoff calls have to be treated differently in terms of resource allocation. Since users are much more sensitive to call dropping than to call blocking, the handoff calls are assigned higher priority than new calls.

CAC techniques are required to guarantee that all traffic types meet their QoS requirements. In order to improve the system performance at the call level (fairness in blocking), a CAC strategy may block additional calls even if there are enough resources for their service. CAC is based on the knowledge of the statistical characteristics of ongoing and arriving calls [22]. The decision to accept an additional call involves the calculation or estimation of the consequences of the call acceptance on blocking and delay of itself and other incoming calls.

Beside the functionality of CAC, bandwidth reservation mechanism helps CAC to decide how much bandwidth is needed to be reserved in order to provide QoS guarantees to mobile users. The bandwidth reservation module, residing in

each BS, dynamically changes the amount of bandwidth to be reserved by referencing traffic conditions in neighboring cells periodically or upon the call request arrival depending on the design of the system.

III. HANDOVER DECISION PROBLEM

Handoffs which are consistently both accurate and timely can result in higher capacity and better overall link quality than what is available with today systems [23], [24]. Now with increasing demands for more system capacity, there is a trend toward smaller cells, also known as microcells. Handoffs are more critical in systems with smaller cells, because for a given average user speed, handoff rates tend to be inversely proportional to cell size [25]. The main objectives of handover are link quality maintenance, interference reduction and keeping the number of handoffs low. Also, a handover algorithm should initiate a handoff if and only if the handoff is necessary. The accuracy of a handover algorithm is based on how the algorithm initiates the handover process. The timing of the handoff initiation is also important. There can be deleterious effects on link quality and interference if the initiation is too early or too late.

Because of large-scale and small-scale fades are frequently encountered in mobile environment, it is very difficult for handover algorithm to make an accurate and timely decision. Handover algorithms operating in real time have to make decisions without the luxury of repeated uncorrelated measurements, or of future signal strength information. It should be noted that some of handover criteria information can be inherently imprecise, or the precise information is difficult to obtain.

For this reason, we propose a FL-based approach, which can operate with imprecision data and can model nonlinear functions with arbitrary complexity.

IV. PROPOSED SYSTEM MODEL

A. FICHS Operation

In this paper, we evaluate the performance of a Fuzzy-based Integrated CAC and Handover System (FICHS) for wireless cellular networks, considering CAC with priority and the case of enforced handover.

In the best of our knowledge, most of the research works deal only with CAC or handover. While, the proposed system integrates CAC and handover and improves the QoS of wireless cellular networks.

The structure of FICHS is shown in Fig. 1. First, after the BS gets the call from Mobile Terminal (MT), it checks whether this is a new generated call or not. If the call is a new generated call then the FACS is activated. If the system has enough bandwidth, then the call is accepted, otherwise the call is rejected and the MT will try again to connect with BS.

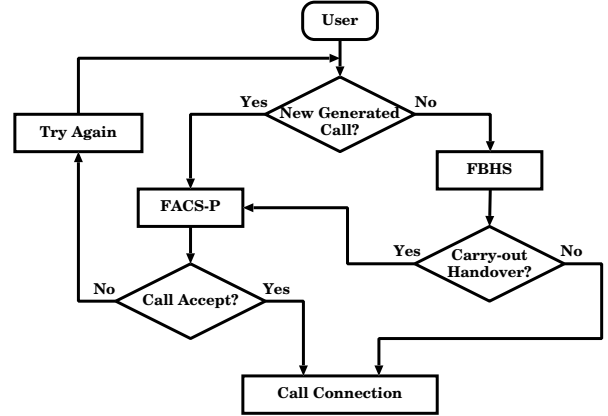


Figure 1: FICHS structure.

When the call is not a new generated call, then the FBHS is activated. The FBHS checks whether the MT moves in the boundary of cells or inside the cell. If the MT is moving inside the cell, the handover is carried out and then the FACS carries out the CAC procedure. Otherwise, in the case when the MT is moving in the boundary of the cells the handover is not carried out and the call is kept connected with the same BS.

The main parts of FICHS are Fuzzy-based Admission Control Scheme with Priority (FACS-P) and Fuzzy-based Handover System (FBHS), which we will explain in following.

B. FACS-P

In our previous work (FACS) [26], we found that the distance did not have a big effect on the CAC decision. For this reason, in the new implemented system, called FACS with Priority (FACS-P) of on-going connections, instead the distance we will use the priority as a new parameter for CAC decision.

The proposed FACS-P considers the following parameters for acceptance decision: user Speed (Sp), user Angle (An), Service request (Sr), Correction value (Cv), Required bandwidth (Rq), Counter state (Cs), Accept or Reject decision (A/R), Differentiated service (Ds), Real Time Counter (RTC), and Non Real Time Counter ($NRTC$). The structure of the proposed FACS-P is shown in Fig. 2.

1) *FLC1 Design*: The input parameters for FLC1 are: user Speed (Sp), user Angle (An), and the bandwidth of the application that we call Service request (Sr), while the output linguistic parameter is Correction value (Cv). The term sets of Sp , An , and Sr are defined respectively as:

$$\begin{aligned}
 T(Sp) &= \{Slow, Middle, Fast\} = \{Sl, Mi, Fa\}; \\
 T(An) &= \{Back1, Left1, Left2, Straight, Right1, Right2, \\
 &\quad Back2\} \\
 &= \{B1, L1, L2, St, R1, R2, B2\}; \\
 T(Sr) &= \{Small, Medium, Big\} = \{Sm, Me, Bi\}.
 \end{aligned}$$

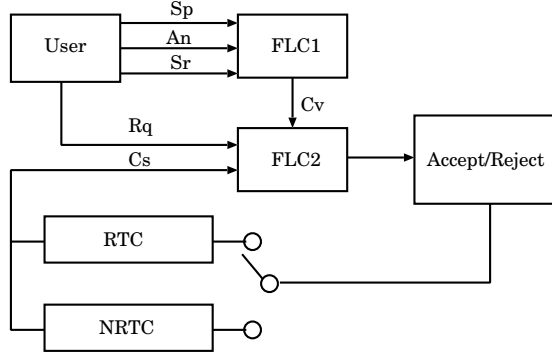


Figure 2: FACS-P proposed model.

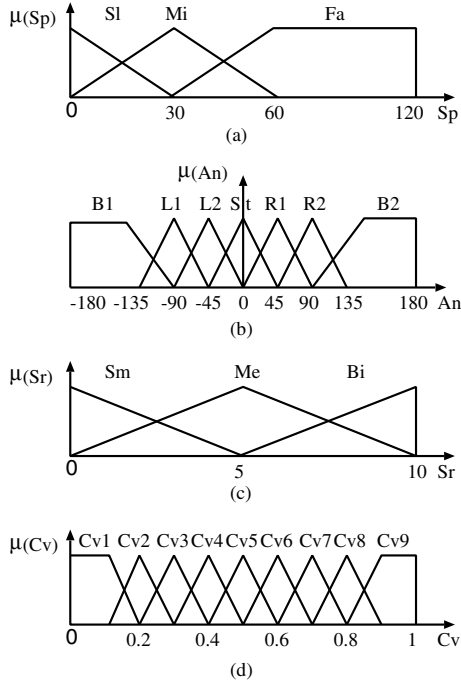


Figure 3: FLC1 membership functions (FACS-P).

The term set of the output linguistic parameter $T(Cv)$ is defined as $\{Correction\ value\ 1, Correction\ value\ 2, \dots, Correction\ value\ 9\} = \{Cv1, Cv2, \dots, Cv9\}$.

The membership functions of FLC1 are shown in Fig. 3 and the FRB is shown in Table I.

2) *FLC2 Design*: For the design of FLC2, the input parameters are: the output parameter of the FLC1 (Cv), user Request (Rq), and the Counter state (Cs), which shows the capacity of the system. While, the output linguistic parameter is the Accept/Reject decision (A/R).

The term sets of Cv , Rq , and Cs are defined as:

$$\begin{aligned} T(Cv) &= \{Bad, Normal, Good\} = \{Bd, No, Go\}; \\ T(Rq) &= \{Text, Voice, Video\} = \{Tx, Vo, Vi\}; \\ T(Cs) &= \{Small, Middle, Full\} = \{Sa, Md, Fu\}. \end{aligned}$$

Table I: FRB of FACS-P (FLC1).

Rule	Sp	An	Sr	Cv	Rule	Sp	An	Sr	Cv
0	Sl	B1	Sm	Cv1	32	Mi	St	Bi	Cv9
1	Sl	B1	Me	Cv3	33	Mi	R1	Sm	Cv1
2	Sl	B1	Bi	Cv2	34	Mi	R1	Me	Cv5
3	Sl	L1	Sm	Cv1	35	Mi	R1	Bi	Cv3
4	Sl	L1	Me	Cv4	36	Mi	R2	Sm	Cv1
5	Sl	L1	Bi	Cv3	37	Mi	R2	Me	Cv4
6	Sl	L2	Sm	Cv2	38	Mi	R2	Bi	Cv3
7	Sl	L2	Me	Cv6	39	Mi	B2	Sm	Cv1
8	Sl	L2	Bi	Cv4	40	Mi	B2	Me	Cv2
9	Sl	St	Sm	Cv5	41	Mi	B2	Bi	Cv1
10	Sl	St	Me	Cv9	42	Fa	B1	Sm	Cv1
11	Sl	St	Bi	Cv7	43	Fa	B1	Me	Cv2
12	Sl	R1	Sm	Cv2	44	Fa	B1	Bi	Cv1
13	Sl	R1	Me	Cv6	45	Fa	L1	Sm	Cv1
14	Sl	R1	Bi	Cv4	46	Fa	L1	Me	Cv3
15	Sl	R2	Sm	Cv1	47	Fa	L1	Bi	Cv2
16	Sl	R2	Me	Cv4	48	Fa	L2	Sm	Cv2
17	Sl	R2	Bi	Cv3	49	Fa	L2	Me	Cv5
18	Sl	B2	Sm	Cv1	50	Fa	L2	Bi	Cv3
19	Sl	B2	Me	Cv3	51	Fa	St	Sm	Cv9
20	Sl	B2	Bi	Cv2	52	Fa	St	Me	Cv9
21	Mi	B1	Sm	Cv1	53	Fa	St	Bi	Cv9
22	Mi	B1	Me	Cv2	54	Fa	R1	Sm	Cv2
23	Mi	B1	Bi	Cv1	55	Fa	R1	Me	Cv5
24	Mi	L1	Sm	Cv1	56	Fa	R1	Bi	Cv3
25	Mi	L1	Me	Cv4	57	Fa	R2	Sm	Cv1
26	Mi	L1	Bi	Cv3	58	Fa	R2	Me	Cv3
27	Mi	L2	Sm	Cv1	59	Fa	R2	Bi	Cv2
28	Mi	L2	Me	Cv5	60	Fa	B2	Sm	Cv1
29	Mi	L2	Bi	Cv3	61	Fa	B2	Me	Cv2
30	Mi	St	Sm	Cv8	62	Fa	B2	Bi	Cv1
31	Mi	St	Me	Cv9					

Table II: FRB of FACS-P (FLC2).

Rule	Cv	R	Cs	A/R
0	Bd	Tx	Sa	A
1	Bd	Tx	Md	NRNA
2	Bd	Tx	Fu	NRNA
3	Bd	Vo	Sa	A
4	Bd	Vo	Md	NRNA
5	Bd	Vo	Fu	WR
6	Bd	Vi	Sa	WA
7	Bd	Vi	Md	NRNA
8	Bd	Vi	Fu	WR
9	No	Tx	Sa	A
10	No	Tx	Md	NRNA
11	No	Tx	Fu	NRNA
12	No	Vo	Sa	A
13	No	Vo	Md	NRNA
14	No	Vo	Fu	NRNA
15	No	Vi	Sa	WA
16	No	Vi	Md	NRNA
17	No	Vi	Fu	NRNA
18	Go	Tx	Sa	A
19	Go	Tx	Md	A
20	Go	Tx	Fu	NRNA
21	Go	Vo	Sa	A
22	Go	Vo	Md	A
23	Go	Vo	Fu	WR
24	Go	Vi	Sa	A
25	Go	Vi	Md	A
26	Go	Vi	Fu	R

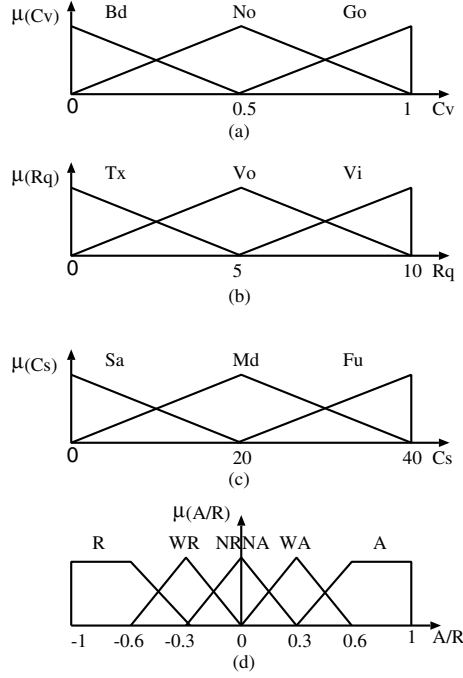


Figure 4: FLC2 membership functions (FACS-P).

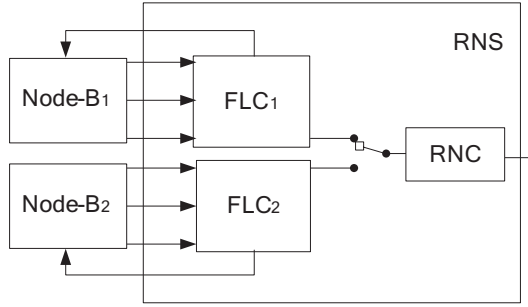


Figure 5: FBHS1 proposed model.

The membership functions for input and output linguistic parameters of FLC2 are shown in Fig. 4 and the FRB is shown in Table II.

The term set of the output linguistic parameter $T(A/R)$ is defined as {Reject, Weak Reject, Not Reject Not Accept, Weak Accept, Accept}. We write for short as {R, WR, NRNA, WA, A}.

C. Design of FBHS1

The FBHS1 model is shown in Fig. 5. The *Node_B* shows the wireless transmitter and receiver of BS and RNS indicates Radio Network System.

As the input linguistic parameters for FBHS1, we consider: Signal Strength from the Present BS (*SSP*), Signal Strength from the Neighbor BS (*SSN*), and the distance of MS from BS (*D*). The output linguistic parameter is

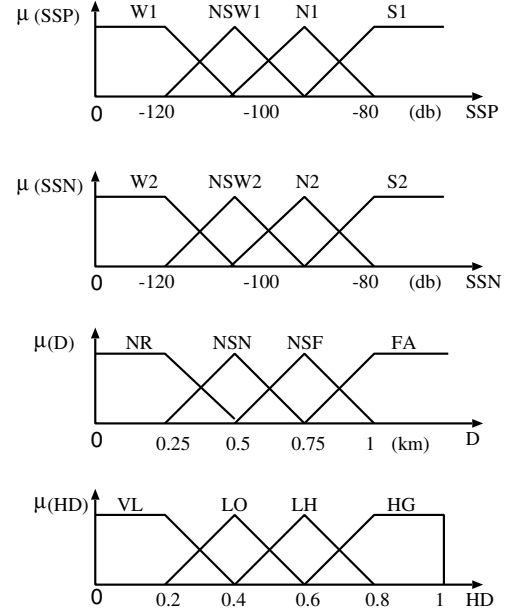


Figure 6: FBHS1 membership functions.

Handover Decision (*HD*).

The term sets of *SSP*, *SSN* and *D* are defined respectively as:

$$\begin{aligned}
 T(SSP) &= \{\text{Weak, Not So Weak, Normal, Strong}\} \\
 &= \{W1, NSW1, N1, S1\}; \\
 T(SSN) &= \{\text{Weak, Not So Weak, Normal, Strong}\} \\
 &= \{W2, NSW2, N2, S2\}; \\
 T(D) &= \{\text{Near, Not So Near, Not So Far, Far}\} \\
 &= \{NR, NSN, NSF, FA\}.
 \end{aligned}$$

The output linguistic parameter $T(HD)$ is defined as {Very Low, Low, Little High, High} = {VL, LO, LH, HG}.

The membership functions of FBHS1 are shown in Fig. 6 and the FRB of FBHS1 is shown in Table III, which has 64 rules.

D. Design of FBHS2

The FBHS2 model is shown in Fig. 7. In this system, the *Node_B* shows the wireless transmitter and receiver of BS, RNS indicates Radio Network System. While, the POTLC stands for Post Test-Loop Controller and PRTLC for Pre Test-Loop Controller.

In FBHS2 we consider as the input parameter the Change of the Signal Strength of Present BS (*CSSP*). While two other parameters: Signal Strength from the Neighbor BS (*SSN*), and the distance of MS from BS (*DMB*) are kept the

Table III: FRB of FBHS1.

Rules	SSP	SSN	D	HD	Rules	SSP	SSN	D	HD
1	W1	W2	NR	VL	33	N1	W2	NR	VL
2	W1	W2	NSN	VL	34	N1	W2	NSN	VL
3	W1	W2	NSF	VL	35	N1	W2	NSF	LO
4	W1	W2	FA	LO	36	N1	W2	FA	LO
5	W1	NSW2	NR	LO	37	N1	NSW2	NR	LO
6	W1	NSW2	NSN	LO	38	N1	NSW2	NSN	LO
7	W1	NSW2	NSF	LO	39	N1	NSW2	NSF	LH
8	W1	NSW2	FA	LH	40	N1	NSW2	FA	LH
9	W1	N2	NR	LH	41	N1	N2	NR	LH
10	W1	N2	NSN	LH	42	N1	N2	NSN	LH
11	W1	N2	NSF	HG	43	N1	N2	NSF	LH
12	W1	N2	FA	HG	44	N1	N2	FA	HG
13	W1	S2	NR	LH	45	N1	S2	NR	LH
14	W1	S2	NSN	LH	46	N1	S2	NSN	LH
15	W1	S2	NSF	LH	47	N1	S2	NSF	LH
16	W1	S2	FA	HG	48	N1	S2	FA	HG
17	NSW1	W2	NR	VL	49	S1	W2	NR	VL
18	NSW1	W2	NSN	VL	50	S1	W2	NSN	VL
19	NSW1	W2	NSF	LO	51	S1	W2	NSF	VL
20	NSW1	W2	FA	LO	52	S1	W2	FA	VL
21	NSW1	NSW2	NR	LO	53	S1	NSW2	NR	VL
22	NSW1	NSW2	NSN	LO	54	S1	NSW2	NSN	VL
23	NSW1	NSW2	NSF	LH	55	S1	NSW2	NSF	VL
24	NSW1	NSW2	FA	LH	56	S1	NSW2	FA	LO
25	NSW1	N2	NR	LH	57	S1	N2	NR	LO
26	NSW1	N2	NSN	LH	58	S1	N2	NSN	LO
27	NSW1	N2	NSF	LH	59	S1	N2	NSF	LO
28	NSW1	N2	FA	HG	60	S1	N2	FA	LH
29	NSW1	S2	NR	LH	61	S1	S2	NR	LO
30	NSW1	S2	NSN	LH	62	S1	S2	NSN	LO
31	NSW1	S2	NSF	LH	63	S1	S2	NSF	LH
32	NSW1	S2	FA	HG	64	S1	S2	FA	LH

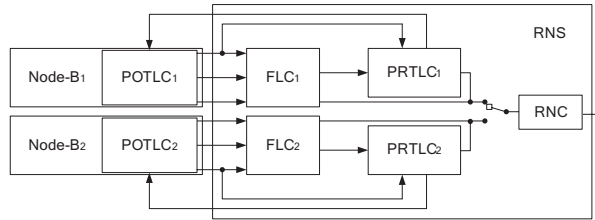


Figure 7: FBHS2 proposed model.

same. The output linguistic parameter is Handover Decision (*HD*).

The FBHS2 operates as follows. First, after receiving the control information from MS, the POTLC check the quality of the signal. If the signal strength is still good enough the handover is not carried out. If the signal strength is lower than a predefined value, then based on *CSSP*, *SSN* and *DMB*, the FLC decides whether the handover is necessary or not. If the handover is not necessary the control is returned to the present BS, otherwise another check of the signal strength is carried out in PRTLC and the present signal strength is compared with the previous signal strength. When the present signal strength is lower than the strength of the previous signal, the handover procedure is carried out.

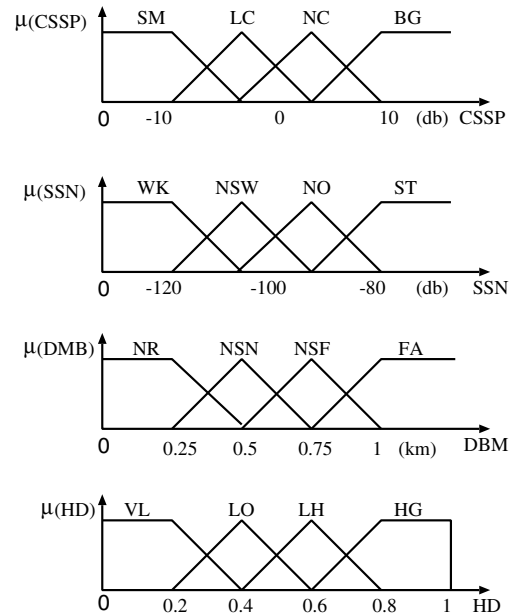


Figure 8: FBHS2 membership functions.

Table IV: FRB of FBHS2.

Rules	CSSP	SSN	DMB	HD	Rules	CSSP	SSN	DMB	HD
1	SM	WK	NR	LO	33	NC	WK	NR	VL
2	SM	WK	NSN	LO	34	NC	WK	NSN	VL
3	SM	WK	NSF	LH	35	NC	WK	NSF	VL
4	SM	WK	FA	LH	36	NC	WK	FA	LO
5	SM	NSW	NR	LO	37	NC	NSW	NR	VL
6	SM	NSW	NSN	LO	38	NC	NSW	NSN	VL
7	SM	NSW	NSF	LH	39	NC	NSW	NSF	VL
8	SM	NSW	FA	LH	40	NC	NSW	FA	LO
9	SM	NO	NR	LH	41	NC	NO	NR	VL
10	SM	NO	NSN	HG	42	NC	NO	NSN	LO
11	SM	NO	NSF	HG	43	NC	NO	NSF	LO
12	SM	NO	FA	HG	44	NC	NO	FA	LH
13	SM	ST	NR	HG	45	NC	ST	NR	LH
14	SM	ST	NSN	HG	46	NC	ST	NSN	LH
15	SM	ST	NSF	HG	47	NC	ST	NSF	HG
16	SM	ST	FA	HG	48	NC	ST	FA	HG
17	LC	WK	NR	VL	49	BG	WK	NR	VL
18	LC	WK	NSN	VL	50	BG	WK	NSN	VL
19	LC	WK	NSF	LO	51	BG	WK	NSF	VL
20	LC	WK	FA	LO	52	BG	WK	FA	VL
21	LC	NSW	NR	LO	53	BG	NSW	NR	VL
22	LC	NSW	NSN	LO	54	BG	NSW	NSN	VL
23	LC	NSW	NSF	LO	55	BG	NSW	NSF	VL
24	LC	NSW	FA	LH	56	BG	NSW	FA	LO
25	LC	NO	NR	LH	57	BG	NO	NR	VL
26	LC	NO	NSN	LH	58	BG	NO	NSN	VL
27	LC	NO	NSF	HG	59	BG	NO	NSF	LO
28	LC	NO	FA	HG	60	BG	NO	FA	LO
29	LC	ST	NR	LH	61	BG	ST	NR	VL
30	LC	ST	NSN	HG	62	BG	ST	NSN	VL
31	LC	ST	NSF	HG	63	BG	ST	NSF	LO
32	LC	ST	FA	HG	64	BG	ST	FA	LO

The term sets of *CSSP*, *SSN* and *DMB* are defined respectively as:

$$\begin{aligned}
T(CSSP) &= \{Small, Little \ Change, No \ Change, Big\} \\
&= \{SM, LC, NC, BG\}; \\
T(SSN) &= \{Weak, Not \ So \ Weak, Normal, Strong\} \\
&= \{WK, NSW, NO, ST\}; \\
T(DMB) &= \{Near, Not \ So \ Near, Not \ So \ Far, Far\} \\
&= \{NR, NSN, NSF, FA\}.
\end{aligned}$$

The output linguistic parameter $T(HD)$ is defined as $\{Very \ Low, Low, Little \ High, High\} = \{VL, LO, LH, HG\}$. The membership functions of FBHS2 are shown in Fig. 8 and the FRB of FBHS2 is shown in Table IV.

V. SIMULATION RESULTS

In this section, we evaluate by computer simulations the performance of FACS-P, FBHS1 and FBHS2.

A. Simulation Consideration for FACS-P

The simulation were carried out in Linux Fedora Core5 computer. We considered the following parameters for simulations: the user speed was from 0 to 120 km/h, the user direction was changed from -180 degree to +180 degree. The required bandwidth for voice, video and text was 30%, 10%, and 60%, respectively. The requested size was 1, 5

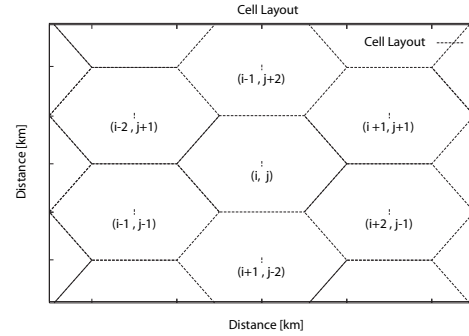


Figure 9: Cell layout.

and 10 Bandwidth Units (BU) for text, voice and video, respectively. The bandwidth of the BS was considered 40 BU. We also considered the distance between users and BS which changed between 0 to 10 km.

B. Simulation Considerations for FBHS Systems

The cell shape is hexagonal and the coordinates of BSs are indicated as shown in Fig. 9. The BS is located in the center of the cell, the transmission antenna power is 10 W, and cell radius is 2 km. In Table V are shown the simulation parameters.

Table V: Simulation parameters.

Distribution Law	Gaussian Distribution
Number of Walks	5 10
Random Types	100 200
Cell Radius	1km 2km
Transmission Power	10W 20W
Frequency	2000MHz
Transmission Antenna Beam Tilting	3°
Transmission Antenna Height	40m
Receiving Antenna Height	1.5m
Average Value for a Walk	0.6km
n	1.1

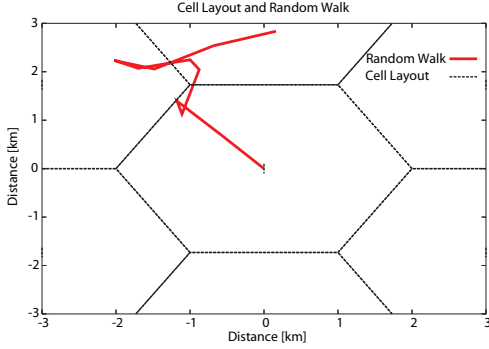


Figure 10: RW pattern.

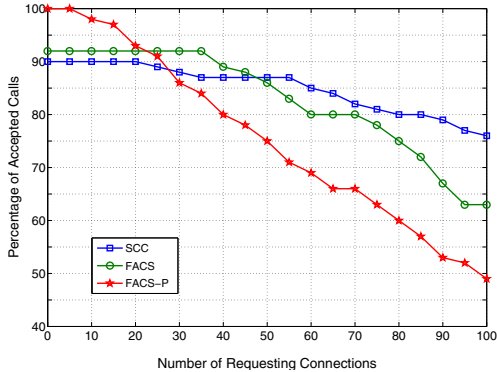


Figure 11: Performance comparison of FACS-P, FACS and SCC.

We considered the handover enforcement scenario for our simulations. In this scenario the MS moves inside the cells, so the handover becomes necessary. In Fig. 10 is shown the movement of MS in the cells, $(0,0) \rightarrow (-1,2) \rightarrow (-2,1) \rightarrow (-1,2)$.

We consider that the handover is carried out when the output value is bigger than 0.7. We assume that during the Random Walk (RW) for each 10 km/h the signal strength is decreased 2 db.

C. Simulation Results for FACS-P

In order to evaluate the performance of the proposed system, we compare its performance with our previous

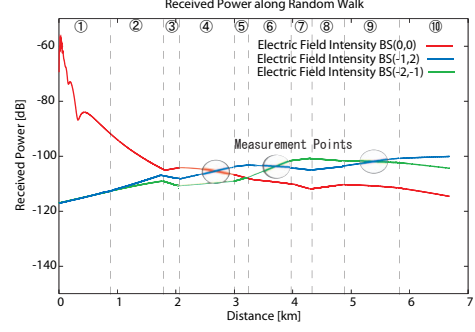


Figure 12: 3 measurement points.

FACS system and the SCC system. The simulation results are shown in Fig. 11. When the number of requesting connections is more than 50, the percentage of accepted calls for SCC is higher than our previous FACS system. FACS guarantees the QoS of calls, so the acceptance ratio of requesting connections is decreased. In the case of FACS-P, when the number of requesting connections is less than 25, the percentage of accepted calls is higher than in our previous FACS system. However, when the number of requesting connections is larger than 25, FACS-P accepts less number of connections. This is because, FACS-P guarantees the QoS of on-going calls, thus decreasing the acceptance ratio of the requesting connections. When the number or requesting connections is smaller FACS-P makes a better allocation of available BU.

D. Simulation Results for FBHS

For evaluation of FBHS, we carried out the measurement, in the case when the handover is necessary because the MS is moving inside the neighbor cells. As shown in Fig. 12, the recieved powers from BS enforce the handover.

We carry out 10 times simulations and calculate the average values. FBHS1 shows a very good behavior (see Table VI). In all 3 measurement points, the FBHS1 carried out 3 handovers, as shown by the values that are greater than 0.7.

The simulation results of FBHS2 are shown in Table VII. FBHS2 has a good performance because in all cases has done 3 handovers. It should be noted that, the performance of FBHS2 is more accurate than FBHS1 because it carries out handovers in values very close but bigger than 0.7.

VI. CONCLUSIONS

In this paper, we evaluated the performance of a Fuzzy-based Integrated CAC and Handover System (FICHS) for wireless cellular networks, considering CAC with priority and the case of enforced handover.

We evaluated the performance of FACS-P comparing it with our previous system FACS and SCC. From the simulations results, we conclude that the FACS-P keeps a

Table VI: Simulation results of FBHS1.

Measurement Points	Point 1		Point 2		Point 3	
Speed 0 km/h						
Present BS	-105.23	-108.70	-104.64	-107.96	-103.95	-111.93
Neighbor BS	-105.55	-102.07	-103.52	-96.763	-103.85	-88.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.596	0.706	0.615	0.748	0.601	0.800
Speed 10 km/h						
Present BS	-107.23	-110.70	-106.64	-109.96	-105.95	-113.93
Neighbor BS	-107.55	-104.07	-105.52	-98.763	-105.85	-90.442
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.595	0.715	0.616	0.799	0.601	0.800
Speed 20 km/h						
Present BS	-109.23	-112.70	-108.64	-111.96	-107.95	-115.93
Neighbor BS	-109.55	-106.07	-107.52	-100.76	-107.85	-92.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.592	0.701	0.699	0.799	0.602	0.800
Speed 30 km/h						
Present BS	-111.23	-114.70	-110.64	-113.96	-109.95	-117.93
Neighbor BS	-111.55	-108.07	-109.52	-102.76	-109.85	-94.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.632	0.705	0.618	0.733	0.603	0.800
Speed 40 km/h						
Present BS	-113.23	-116.70	-112.64	-115.96	-111.95	-119.93
Neighbor BS	-113.55	-110.07	-111.52	-104.76	-111.85	-96.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.602	0.711	0.660	0.711	0.647	0.800
Speed 50 km/h						
Present BS	-115.23	-118.70	-114.64	-117.96	-113.95	-121.93
Neighbor BS	-115.55	-112.07	-113.52	-106.76	-113.85	-98.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.693	0.746	0.694	0.748	0.683	0.800

higher QoS of on-going connections, thus decreasing the acceptance rate of requesting connections.

We also evaluated the performance of two FL-based handover systems for enforced handover scenario. Both FBHS1 and FBHS2 have a good performance because in all cases have done 3 handovers. However, the FBHS2 is more accurate than FBHS1

In this paper, we considered only the priority of ongoing connections. In the future, we would like to consider also the priority of requesting connections.

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Table VII: Simulation results of FBHS2.

Measurement Points	Point 1		Point 2		Point 3	
Speed 0 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-105.55	-102.07	-103.52	-96.763	-103.85	-88.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.645	0.745	0.634	0.740	0.692	0.730
Speed 10 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-107.55	-104.07	-105.52	-98.763	-105.85	-90.442
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.632	0.780	0.634	0.710	0.671	0.730
Speed 20 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-109.55	-106.07	-107.52	-100.76	-107.85	-92.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.616	0.777	0.620	0.726	0.633	0.730
Speed 30 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-111.55	-108.07	-109.52	-102.76	-109.85	-94.422
Distance	1.9597	2.4628	1.8367	2.3453	1.8021	3.0449
System Output Value	0.596	0.743	0.597	0.756	0.606	0.730
Speed 40 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-113.55	-110.07	-111.52	-104.76	-111.85	-96.422
Distance	0.3536	0.4821	0.6824	0.9047	1.3158	1.4976
System Output Value	0.576	0.715	0.574	0.794	0.591	0.728
Speed 50 km/h						
CSSP BS	-2.0149	-3.4731	-2.1681	-3.7153	-7.1891	-7.9733
Neighbor BS	-115.55	-112.07	-113.52	-106.76	-113.85	-98.422
Distance	0.3536	0.4821	0.6824	0.9047	1.3158	1.4976
System Output Value	0.545	0.703	0.553	0.713	0.579	0.703

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