Service Aware Fuzzy Logic Based Handover Decision in Heterogeneous Wireless Networks

by

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A project submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical and Electronic Engineering

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Declaration

This is to certify that the project work entitled ***"Service Aware Fuzzy Logic Based Handover Decision in Heterogeneous Wireless Networks"*** has been carried out by **Mehek-Moutushy Rahman Mou** in the Department of Electrical and Electronic Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh. The above research work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Signature of Supervisor	Signature of Candidate

Approval

This is to certify that the project work submitted by **Mehek-Moutushy Rahman Mou** entitled ***"Service Aware Fuzzy Logic Based Handover Decision in Heterogeneous Wireless Networks"*** has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of **Master of Science (M. Sc.)** in the Department of **Electrical and Electronic Engineering**, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in November 2016.

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Dedicated to my loving parents

Md. Fazlur Rahman & Maharan Nesa

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Acronyms

4G	4^{th} Generation
5G	5^{th} Generation
BS	Base Station
CATV	Cable Television
DSL	Digital Subscriber Line
FAPs	Femto Access Points
FIS	Fuzzy Inference System
FMC	Fixed Mobile Convergence
FTTx	Fiber To The X (X = anything)
FUE	Femtocell User Equipment
MF	Membership Function
MS	Mobile Station
PBX	Private Branch Exchange
PCSs	Permanent Change of Stations
PLC	Power Line Communications
QoE	Quality of Experience
QoS	Quality of Service
RSSI	Received Signal Strength Indicator
SNIR	Signal-to-Noise Plus Interference Ratio
UMA	Unlicensed Mobile Access
VoIP	Voice Over Internet Protocol
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network

Abstract

The ubiquitous services of wireless communication networks are growing rapidly by the development of wireless communication technologies. While a user is roaming from one cell to another cell, an intelligent decision mechanism and network selection is extremely crucial to maintain the quality of service (QoS) during handover. Handover decision must be made preciously to avoid any unnecessary phenomenon like ping-pong, corner effect, call blocking, and call dropping etc. In addition, the handover decision must be very efficient and cost-effective. Particular services require diverse level of QoS and different networks provide different level of service in terms of throughput, mobility, jitter, security, price, etc. This work considered service types like voice, video, and data and their QoS requirements for handover decision using fuzzy logic in heterogeneous network environment. Service is an important factor for the users and particular service requires respective QoS. This research provides all the cases of handover decisions between macrocell and femtocell networks considering service type. The proposed system models regarding these handover decisions using fuzzy logic, considering several input parameters e.g. received signal strength indicator (RSSI), data rate, user's velocity, and interference level (signal-to-noise plus interference ratio) are shown. All handover cases in macrocell/femtocell integrated network such as femtocell to macrocell, macrocell to femtocell or femtocell to femtocell are addressed in this research. The performance of different parameters are shown based on service type are analyzed.

Key Words: Handover, femtocell, macrocell to femtocell, femtocell to macrocell, femtocell to femtocell, handover factor, quality of service, throughput, and fuzzy logic.

Chapter 1

Introduction

Next generation wireless communication needs seamless connectivity with high level of quality of service (QoS), high data rate services, favorable price, and multimedia applications among different access networks. Heterogeneous networks are the combination of different networks which can provide different services and quality with verity of features. So handover is a common criterion in heterogeneous network and efficient handover decision is an important issue [1]. The mechanism of transferring an ongoing call from one cell to another or a mobile user switching from one network to another is called handover process. Handover is one of the challenging issues right now as communication is progressing from 4G to 5G [2]. There are many wireless technologies which require interconnection like macrocell, femtocell, and WLAN. Handover is a process that determine the best expected access network and decide at any particular time whether to carry out handover or not [3], [4]. If the handover occurs between different wireless technologies, then it is considered as vertical handover. On the other hand, if it occurs among same wireless technology, then it is considered as horizontal handover. Network selection is one of the major issues, because without selecting proper network our purposes of handover is not fulfilled [5-7]. Macrocell can support high mobility, whereas femtocell cannot support high mobility. The use of macrocellular network is more expensive. We know different services need different QoS parameters for preference [8], [9]. Some services prefer macrocell with better QoS level. On the other hand, some favor femtocell, since femtocell cannot support high mobility but femocell can support high data rate and good throughput. The cost of femtocellular network is low as well.

Femtocellular technology is widely deployed in subscribers' homes to provide high data rate communications with better QoS [10]. The femto-access-points (FAPs) enhance the service quality for the indoor mobile users. Some key advantages of femtocellular network technology are the improved coverage, reduced infrastructure and the capital costs, low power consumption, improved signal-to-noise plus interference ratio (SNIR) level at the mobile station (MS), and improved throughput. Femtocells operate in the spectrum licensed for cellular service providers [11], [12].

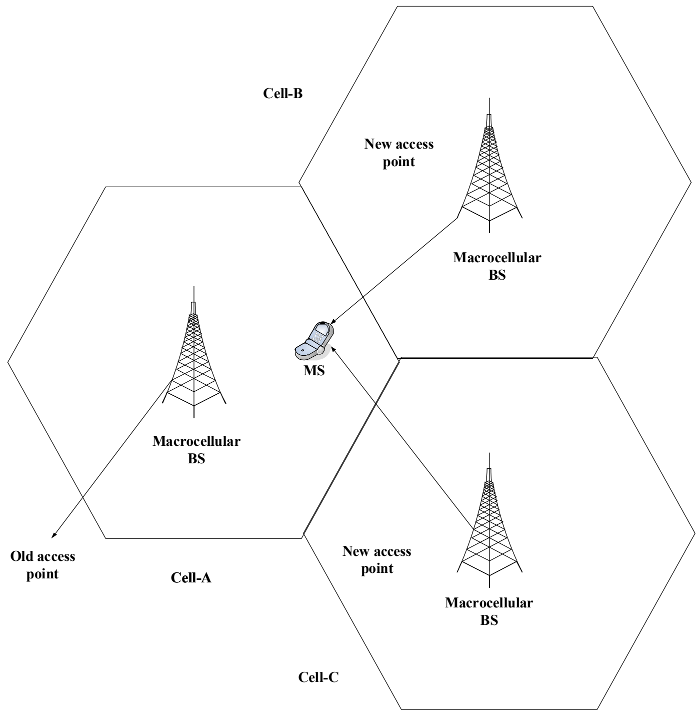


Fig. 1.1 Handover scenarios of cellular network

Fig. 1.1 shows the general handover scenarios of cellular network. Handover decision is one of the major issues of wireless communication [13]. When a mobile user moves into a different cell while a conversation is in progress, the mobile station automatically transfers the call to a new channel belonging to the new base station. Processing handover is an important task in any cellular radio system. Many handover strategies prioritize handover requests over call initiation requests when allocating unused channel in a call site. Handover must be performed successfully and as frequent as possible to the users. Another important requirement for handover decision is network selection [14-16]. With the rapid development of mobile industry, there is rapid growth of number of mobile users, due to which there is drastic requirement to integrate heterogeneous access networks and technologies for supporting ubiquitous communication and seamless mobile computing. Without proper selection of network based on user service and availability of network space our handover decision may fail. So network selection should be done in rightly manner.

In the past, a few literatures about fuzzy-based solution for vertical handover decision systems have been proposed [17]-[19]**.** A fuzzy-based vertical handover decision algorithm which assumes interconnection between WLAN and WMAN was proposed in [20]. The decision parameters considered here were: RSSI, data rate, usage cost, and user preference. Previous researchers considered only one case (one direction of handover) and handover occurred from WMAN to WLAN but they did not consider user's velocity and services during handover decision. In a more recent work, handover decision using a Kalman filter and fuzzy logic in heterogeneous wireless networks has shown handover decision from cellular networks to WLAN [21]. In this research, we consider three different handover scenarios, e.g. femtocell to femtocell, femtocell to macrocell, and macrocell to femtocell. Femtocell is small coverage area so it's tolerance of high mobility is less than macrocell. Therefore, we included velocity as a handover selection parameter for both networks. This research also emphasizes on service type as handover decision parameters. In previous years researcher considered different networks like WLAN, cellular network, WMAN, WiMAX for handover but they did not consider multi cases for handover between macrocell and femtocell [22]. However, here we are mentioning all probable cases of handover considering service priority during handover. In the past, researcher did not consider service types with fuzzy logic during handover decision. But here we show this new strategy of handover decision with service priority. Previous researches only consider one direction of handover but we consider two or multi directions of handover. Handover between macrocell and femtocell including service type as input of fuzzy logic is new concept which we focus on this research.

1.1 Statement of problems

Spectrum is very important in wireless communications. Spectrum and resources are limited as well as precious. We should use resources in careful manner. If we can use small cellular networks within macrocellular network then it will be helpful to decrease traffic load in macrocell. With the invention of modern technologies people use modern devices, for example people use smart phone which has various applications. Now people use different applications besides voice call which creates overload of cellular networks than before. To reduce the network congestion and load of macrocell, small cells like femtocell are used. Another problem of network is handover where call switch from one cell to another. In this case the probability of call termination may increase. Even sometimes cells are not capable of holding new arrival calls or handover calls. This may terminate calls. If macrocells contain overlaid femtocellular networks, then available networks are macrocelluar and femtocelluar networks. Then a question arises that, "which network is better for it?". Femtocell is small cell so its coverage area is too small. Hence, frequent handover may occur in this network, which may create problems. In this case if we divide our services among different networks depending on our importance, then traffic load may decrease and call holding capacity of calls may increase. So intelligence and smooth handover decision is crucial. There are various network parameters exist in the cellular networks and, different services require different parameters. Various services, like voice gives importance on delay and RSSI whereas video gives importance on throughput. There are various services in wireless communication such as voice, video, video streaming, conference call, data, multimedia message, and so on [23]. Handover frequently happens from cell to cell. However, if we use same handover technique for all services, then it will not be effective for seamless communication. So handover mechanism using fuzzy logic is a new approach which performance is better than existing traditional handover mechanism.

1.2 Research objectives

The aim of this research is to design an intelligent handover decision process considering service type macrocell/femtocell integrated network.

1.2.1 Handover decision using fuzzy logic

In this research, All handover cases in macrocell/femtocell integrated network such as femtocell to marcocell or macrocell to femtocell or femtocell to femtocell are addressed in this research. Therefore, effective handover decision process is necessary. Unnecessary and inefficient handover create problem in communication system .To solve these problems, we designed an intelligent handover decision using fuzzy logic. Here we use fuzzy logic for making this handover decision. We use four fuzzy inputs (RSSI, data rate, velocity, and SNIR) and three membership functions Low, Medium, and High. In fuzzy logic the maximum possible number of rules in our rule base is $3^4 = 81$rules. Membership function of handover factors have six catagories Lower, Low, Lower medium, Higher medium, High, and Higher levels. Here we use voice, video, and data services depending on importance of user choice.

1.2.2 New system models based on user service

Here we design new system models for handover decision. In this model, firstly the system detects the service type which is needed for the user, and then fuzzy logic executes the mechanism and provides a handover factor. After that, handover decision may finally deliver between macrocell and femtocell. Lastly, it compares the performance parameter between voice and video services. Handover preference between macrocell and femtocell networks are shown here. Other services may be compared with the same manner.

Chapter 2

Femtocell and Macrocell Network Deployment

Modern wireless communication systems aim to provide users with the convenience of seamless connection to access various wireless technologies and try to support ubiquitous services among the users. The wireless networks use multiple technologies that offer unrestricted user access to different services [24]. With the development of communication technology, the services of wireless networks are upgrading fast. There are many wireless networks like macrocellular, microcellular, picocellular, femtocellular networks. We can define a cellular network as a communication network where the last link is wireless. The network is distributed over land areas is called cells which can be macro, micro, or pico cells, each served by the least one fixed location transceiver known as base station. This base station provides the cell with the network coverage which can be used for transmission of voice, data and others. A cell might use a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed QoS with each cells. When joined together, these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceiver such as mobile phones, tablet pc, to communicate with each other and with fixed transceivers and telephones anywhere in the networks via base stations, even if some of the transceivers are moving through more than one call during transmission. A macrocell is a cell in a mobile phone that provides radio coverage served by a high power cellular base station [25]. The antennas for macrocells are mounted on ground-based masts, rooftops, and other existing structures, at a height that provides a clear view over the surrounding buildings and terrain. Fig. 2.1 shows the basic architecture of macrocellular network (4G).

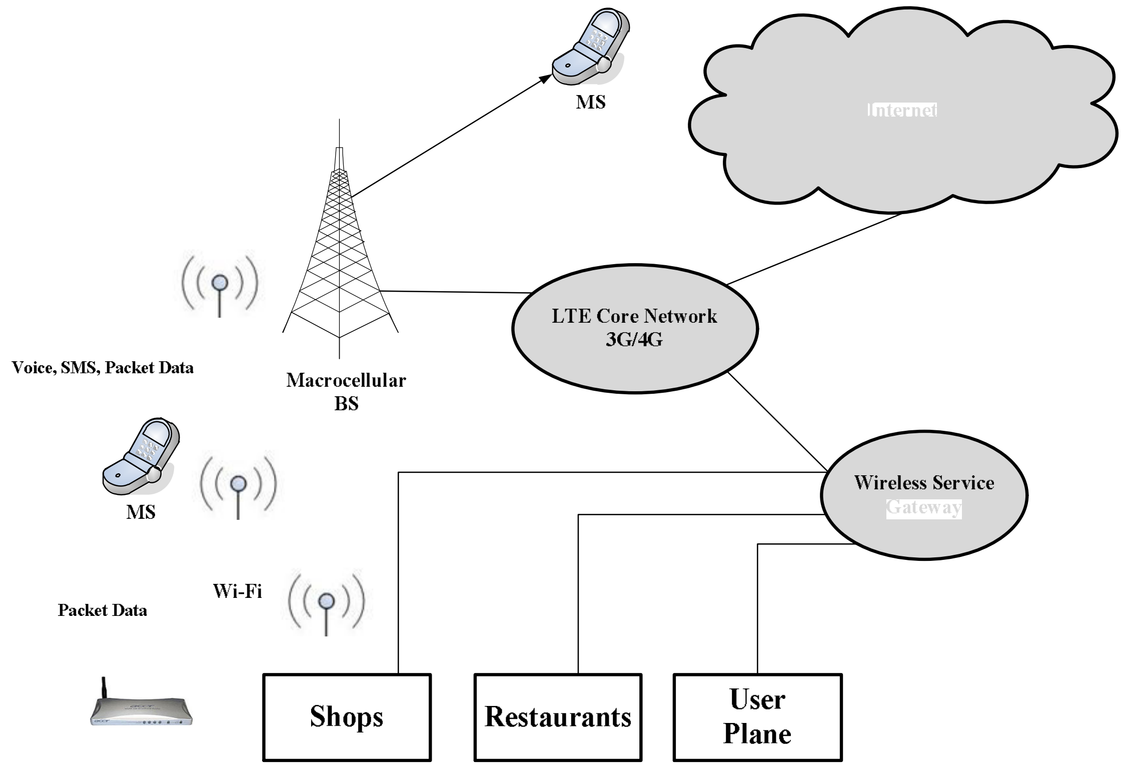


Fig. 2.1 Macrocellular network deployment (4G)

In communications, a femtocell is a small, low-power cellular base station, typically designed for use in a home or small business. A broader term which is more widespread in the industry is small cell, with femtocell as a subset. It connects to the service provider's network via broadband such as DSL or cable. The femto-access-points (FAPs) enhance the service quality for the indoor mobile users. Some key advantages of femtocellular network technology are the improved coverage, reduced infrastructure and the capital costs, low power consumption, improved SNIR level at the mobile station (MS), and improved throughput [26]. Femtocells operate in the spectrum licensed for cellular service providers thus, it can provide high performance. Also no need to use the dual mode terminal for this technology, whereas WLAN needs dual mode terminal and hence, the key feature of the femtocell technology is that user does not require any new femtocell user equipment (FUE) [27], [28]. One of the key advantages of the femtocellular technology is in the fact that it uses the same frequency bands as the macrocellular networks, thus avoiding the need to introduce new user equipment. However, the use of the same frequency spectrum can also cause substantial interference if no adequate interference management is incorporated into the network design, infrastructure,

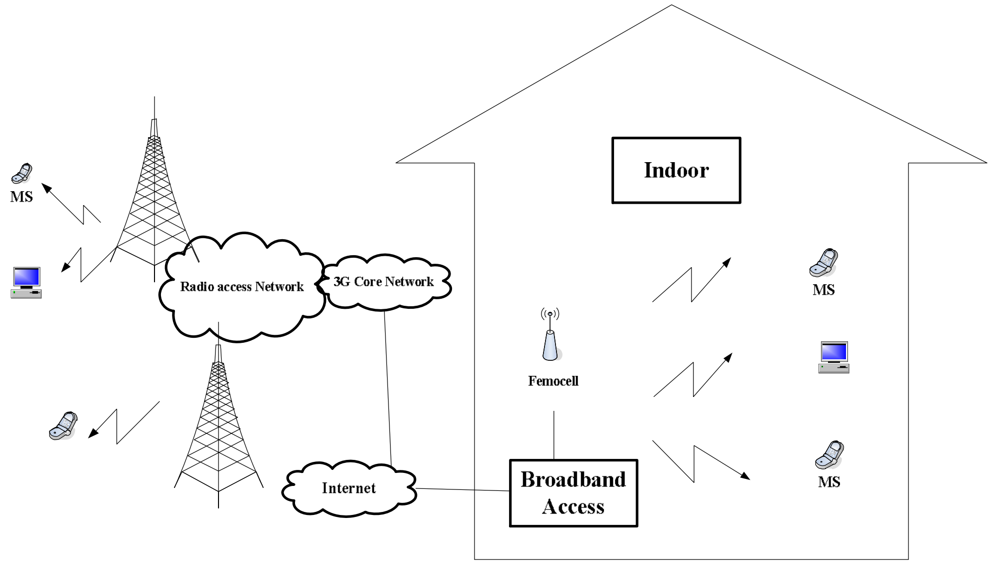


Fig. 2.2 Femtocell network deployment

and the future extension plan. Interference between two or more femtocells could be managed through on-demand scheme along with proper frequency allocation scheme, which would allow largest utilization of the valuable radio spectrum and the highest level of user's quality of experience (QoE). Although the interference in a femtocellular network cannot be fully eliminated, it is possible to reduce the interference to within a reasonable range by proper management. Fig. 2.2 shows the basic femtocell network deployment. In this figure the femtocell serves the indoor coverage area. If a macrocell users enter this indoor area then this macrocell users served by the femtocell network and include this femtocell network.

2.1 Main advantages of femtocell network architecture

Femtocell is a low cost, more reliable, less power utilizing network deployment planning for future cellular system with a small coverage area. The wireless engineering community has been searching for low-cost indoor coverage solutions since the beginning of mobile networks. Femtocellular network technology is one of such solutions. Use of femtocells benefits both the mobile operator and the consumer. The range of a femtocell is about 10m.

There are some basic or key advantages of using femtocell network in the perspective of network operator [10], [11]

- **Enhanced coverage:** For a mobile operator, the attractions of a femtocell are improvements to both coverage, especially indoors, and capacity. Coverage is improved because femtocells can fill in the gaps and eliminate loss of signal through buildings. Capacity is improved by a reduction in the number of phones attempting to use the main network cells and by the off-load of traffic through the user's network (via the internet) to the operator's infrastructure. Instead of using the operator's private network (microwave links, etc.), the internet is used. Consumers benefit from improved coverage since they have a base-station inside their building.
- **Longer battery life:** The mobile phone (user equipment) achieves the same or higher data rates using less power, thus battery life is longer. They may also get better voice quality
- **High capacity:** Higher mobile data capacity, which is important if the end-user makes use of mobile data on his or her mobile phone, may not be relevant to a large number of subscribers who instead use WiFi where femtocell is located.
- **Licensed spectrum:** Femocell operates in licensed spectrum so It needs not additional spectrum as it can use cellular spectrum. Femtocell transmits licensed frequencies which belong of different network operators in different countries.
- **Reduced cellular network congestion:** Femtocell provide better indoor coverage as full speed data transfer at home and ubiquitous mobility between home cell and overlaying macrocell. We can use femtocell where network is too much peak used as more network traffic. As a result, network congestion may reduce.
- **Low cost:** Femtocells are low cost volume product. It is automated installation process. Femtocell use the existing home broadband connectivity for backhauling the femtocells' traffic. Thus, by steering users' traffic into their own FAPs and away from the macrocells, femtocells reduce the cost of macrocellular networks.
- **Security:** Femtocells use the same over-the-air security mechanisms that are used in macrocell radio networks. But additional security capabilities need to be supported to protect against threats that originate from the Internet or through tampering with the femtocell itself. Femtocell network architecture provides network access security, and includes subscriber and femtocell authentication and authorization procedures to protect against fraud.
- **Scalability:** Femtocell networks can have millions of access points. Therefore, the femtocell network architecture must be scalable to grow into such large networks, while at the same time maintaining reliability and manageability.

- **Self-Installation & Simple Operational Management:** Femtocells are installed by end-users. Therefore, the femtocell network architecture must support an extremely simple installation procedure with automatic configuration of the femtocell and automated operational management with "zero-touch" by the end.

2.2 Different path loss models

Signal coverage is essential for deployment of both narrowband and wideband wireless communication and calculation is important for design as well. Signal coverage is influenced by a variety of factors most prominently the radio frequency of operation and the terrain. Often the region where a wireless network is providing service spans a variety of terrain. An operation scenario is defined by a set of operations for which a variety of distances and environments exist between the transmitter and receiver. As a result, a unique channel model cannot describe radio propagation between transmitter and receiver [29]. So various model for variety of environments are needed to enable system design.

2.2.1 Path loss models for megacellular network

Megacellular areas are those where the communication is over extremely large cells spanning hundreds of kilometers. Megacells are served mostly by mobile satellites usually low earth orbiting LEO. The path loss is usually the same as that of free space, but the fading characteristics are somewhat different.

2.2.2 Path loss model for macrocellular network

Macrocellular areas span a few kilometers to ten of kilometers, depending on the location. There are the traditional cells corresponding to the coverage area of a base station associated with traditional cellular telephony base stations. The most popular model was Okumura, which included frequency, height of base station antenna, and height of mobile antenna as important parameters. Then Masaharu Hata created empirical models that good fit for the measurements taken by Okumura for transmitter-receiver separation. The expression for path loss development by Hata is called the Okumura-Hata models [29], [30].

$$L = 69.55 + 26.16\log_{10} f_{c,m} - 13.82\log_{10}(h_b) - a(h_m) + [44.9 - 6.55\log_{10} h_b]\log_{10} d + L_{sh} \text{ [dB]} \quad (1)$$

$$a(h_m) = 1.1\left[\log_{10} f_{c,m} - 0.7\right]h_m - (1.56\log_{10} f_{c,m} - 0.8) \quad (2)$$

where L is the path loss, $f_{c,m}$ is the center frequency in MHz of the macrocell, h_b is the height of the macrocellular BS in mater, h_m is the height of the MS in meter, d is the distance between the macrocellular BS and the MS in kilometer, L_{sh} is the shadowing standard deviation.

2.2.3 Path loss model for microcellular network

Microcells are cells that span hundreds of meters to a kilometer or so and are usually supported by below rooftop level base station antennas mounted on lampposts or utility poles. The shapes of microcells are also no longer circular because they are deployed in the streets in urban areas where tall buildings create urban canyons. There is little or no propagation of signals through buildings and the shape of microcell is more like a cross or a rectangle depending on the placement of base station antenna at the intersection of streets or in between intersections. The propagation characteristics are quite complex with the propagation of signal affected by reflection from buildings and the ground and scattering from nearby vehicles. Path loss model for microcellular areas are given below [31],

$$L = \begin{cases} 10n_1 \log_{10} r + L_1, & r \le r_b \\ 10n_2 \log_{10}\left(\dfrac{r}{r_b}\right) + 10n1\log_{10} r_b + L_1, & r > r_b \end{cases} \tag{3}$$

where, L_1= reference path loss at r =1 m, r_b= breakpoint distance, n_1= path loss exponent for r =< r_b, n_2= path loss exponent for r> r_b

2.2.4 Path loss model for picocellular network

Picocells correspond to radio cells covering a building or pars of buildings. The span of picocells are anywhere between 30m and 100m. Usually picocells are employed for WLANs, wireless PBX systems and PCSs operating in indoors areas. Characterize indoor path loss for picocellular areas by a fixed exponent of 2 (as in free space) + additional loss factors relating to number of floors n_f and walls n_w intersected by the straight-line distance r between terminals [31],

$$L = L_1 + 20\log r + n_f a_f + n_w a_w \tag{4}$$

where, a_f is the attenuation factor per floor, a_w is the attenuation factor per wall, L_1 is the reference path loss at r =1 m.

2.2.5 Path loss model for femtocellular network

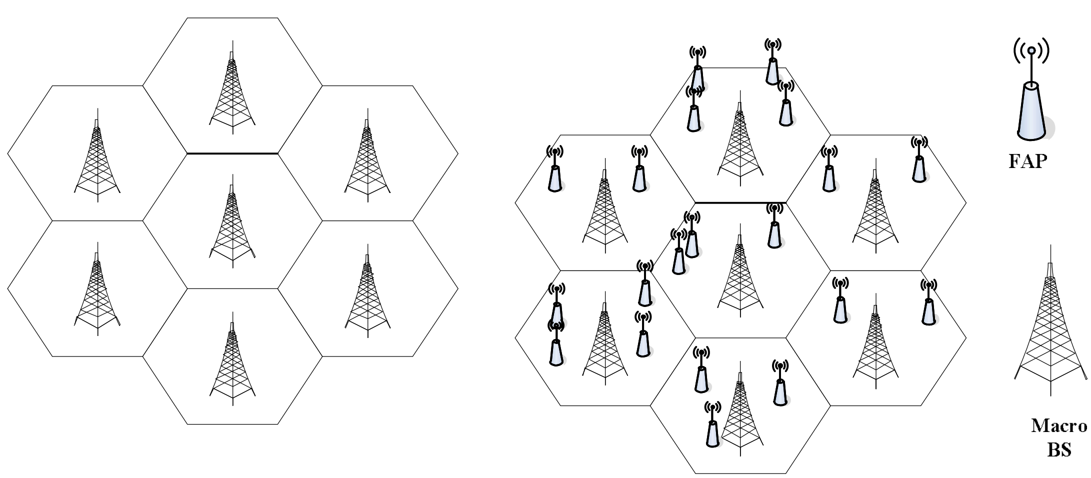
Femto-access points (FAPs) are low power, small sized home placed base stations that create islands of increased capacity in addition to the capacity provided by the cellular system. These areas of increased capacity are referred to as femtocells. Femtocells operate in the licensed for cellular service providers. The key feature of the femtocell technology is that users require no new equipment. The propagation model for femtocell users can be expressed as [12]

$$L_{femto} = 20\log_{10} f_{c,f} + N\log_{10} d_1 - 28 \quad [\text{dB}] \tag{5}$$

where $f_{c,f}$ is the center frequency in MHz of the femtocell, d_1 is the distance between the FAP and the MS in meter.

2.3 Comparison among existing network technologies

There are various technical methods to improve the indoor coverage; femtocell appears to be the most attractive away. Compared with the fixed mobile convergence (FMC) framework, femtocell allows servicing large number of indoor users. Femtocells are fully featured for very low power single mode mobile phone. As a result, dual mode handset is not required. The connection of femtocell uses standard broadband DSL, Cable, FTTx, PLC, WiMAX, etc. The drawback of Wi-Fi is its use of the increasingly crowded unlicensed ISM band that causes significant interference. Finally, repeaters improve the wireless access coverage, but not the wireless capacity. Repeaters need new backhaul connections and only solve the poor coverage problem in remote areas, where fixed broadband penetration is low. Fig. 3 shows



(a) (b)

Fig. 2.3 (a) Macrocell and (b) macrocell overlaid femtocell networks deployment.

(a) macrocelluar networks deployment and (b) femocellular network deployment in macrocells. Table 1 shows the comparison between macrocell and femtocell technologies. Table 2 provides the comparison among the repeater, FAP, and Wi-Fi technologies [10].

Table 1.1 Comparison between the macrocell and femtocell

Feature	Macrocell	Femtocell
Network	Few number of BS	Large number of FAP should be supported by network.
Way of deployment	Deployed by the operator in a controlled way	Typically deployed by the customer in an uncontrolled way.
Environment	The environment of each node is well known.	The environment of FAP is not known.
Access node	Access node are on safe locations and integral part of the network	FAPs are on customer premises but still an integral part of the network.
Configuration	Autonomous O&M is preferable but manual configuration is possible.	Autonomous O&M is mandatory.

Table 1.2 Technical solutions for indoor poor coverage

Feature \solutions	FAP	Repeater or signal booster	3G/Wi-Fi UMA
Installing infrastructure	Existing xDSL or CATV connection	Needs new connection	Existing Wi-Fi connection
Coverage	In indoor, hot spot or remote area where cellular voice or data services are required	Solves poor coverage issues in remote areas where fixed broadband penetration is low	In indoor, hot spot or remote area where cellular data services are required
Terminal mode	Single mode	Single mode	Dual mode
Data speed	High	Low	High

Chapter 3

Fuzzy Logic System

Fuzzy logic has rapidly become one of the most successful of today's technologies for developing sophisticated control systems. The reason for which is very simple. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (e.g. linear control design), and purely logic-based approaches (e.g. expert systems) in system design. Fuzzy logic is not logic that is fuzzy, but logic that is used to describe fuzziness. Fuzzy logic is the theory of fuzzy sets, sets that calibrate vagueness. Fuzzy logic is based on the idea that all things admit of degrees. Temperature, height, speed, distance, beauty all comes on a sliding scale. Boolean logic uses sharp distinctions. It forces us to draw lines between members of a class and non- members. Fuzzy logic reflects how people think. It attempts to model our sense of words, our decision making and our common sense. As a result, it is leading to new intelligent systems [32].

3.1 Concept and applications of fuzzy system

Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership. Unlike two-valued Boolean logic, fuzzy logic is multi-valued. It deals with degrees of membership and degrees of truth. Fuzzy logic uses the continuum of logical values between 0 (completely false) and 1 (completely true). Instead of just black and white, it employs the spectrum of colors, accepting that things can be partly true and partly false at the same time [33]. The basic architecture of a fuzzy logic system is shown in Fig. 3.1.

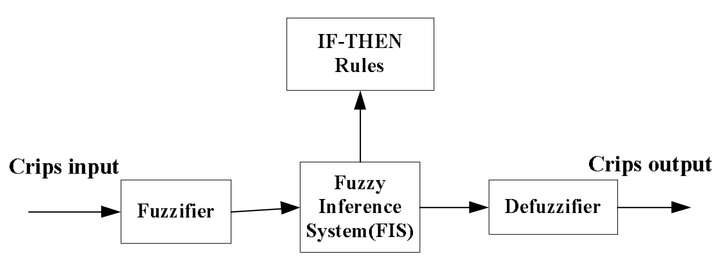


Fig. 3.1 Basic architecture of Fuzzy logic system

It consists of four components fuzzifier, knowledge based IF-THEN rules, fuzzy inference system (FIS) and defuzzifier.

- A **Fuzzifier** transforms the crips inputs into degrees of the functional blocks.
- A **Fuzzy rule base** contains a number of fuzzy IF-THEN rules.
- A **Data base** defines the membership functions of the fuzzy sets used in the fuzzy rules.
- A **Fuzzy Inference System** performs the inference operators on the fuzzy rules.
- A **Defizzifier** transforms the fuzzy results of the inference into a crips output.

Fuzzy logic has a history of how it is introduced. Fuzzy Logic is particularly good at handling uncertainty, vagueness and imprecision. This is especially useful when a problem can be described linguistically (using words) or, as with neural networks, where there is data and the relationships or patterns within that data. Fuzzy Logic uses imprecision to provide robust, tractable solutions to problems. Fuzzy, or multi-valued logic was introduced in the 1930s by Jan Lukasiewicz , a Polish philosopher. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to all real numbers in the interval between 0 and 1. He used a number in this interval to represent the possibility that a given statement was true or false. This work led to an inexact reasoning technique often called possibility theory. Then In 1965 LotfiZadeh, published his famous paper “Fuzzy sets”. Zadeh extended the work on possibility theory into a formal system of mathematical logic, and introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called fuzzy logic, and Zadeh became the Master of fuzzy logic [34].

Applications of fuzzy system:

- The first applications of fuzzy theory were primarily industrial, such as process control for cement kilns.

- Since then, the applications of Fuzzy Logic technology have virtually exploded, affecting things we use everyday life. Take for example, the fuzzy washing machine.

- A load of clothes in it and press start, and the machine begins to turn, automatically choosing the best cycle. The fuzzy microwave, place chili, potatoes, or etc in a fuzzy microwave and push single button, and it cooks for the right time at the proper temperature.

- The fuzzy car, maneuvers itself by following simple verbal instructions from its driver. It can even stop itself immediately when there is an obstacle ahead using sensors.

3.3.1 Fuzzy sets

The concept of a set is fundamental to mathematics. Fuzzy sets are fully defined by its membership functions. Membership function is a function in [0,1] that represents the degree of belonging A fuzzy set is a set with fuzzy boundaries. Let *X* be the universe of discourse and its elements be denoted as *x*. In the classical set theory, crisp set *A* of *X* is defined as function f_A(x) called the characteristic function of *A*. $f_A(x)$: *X* ® {0, 1},where

$$f_A(x) = \begin{Bmatrix} 1, x \in A \\ 0, x \notin A \end{Bmatrix} \tag{6}$$

This set maps universe *X* to a set of two elements. For any element *x* of universe *X*, characteristic function $f_A(x)$ is equal to 1 if *x* is an element of set *A*, and is equal to 0 if *x* is not an element of *A*.

Fig. 3.2 determines the membership functions of the Crisp and fuzzy sets of short, average and tall men. Here fuzzy sets of tall, short and average men. The universe of discourse – the men's heights – consists of three sets: short, average and tall men. As we will see, a man who is 184 cm tall is a member of the average men set with a degree of membership of 0.1, and at the same time, he is also a member of the tall men set with a degree of 0.4.That theory of fuzzy sets represent in computer.

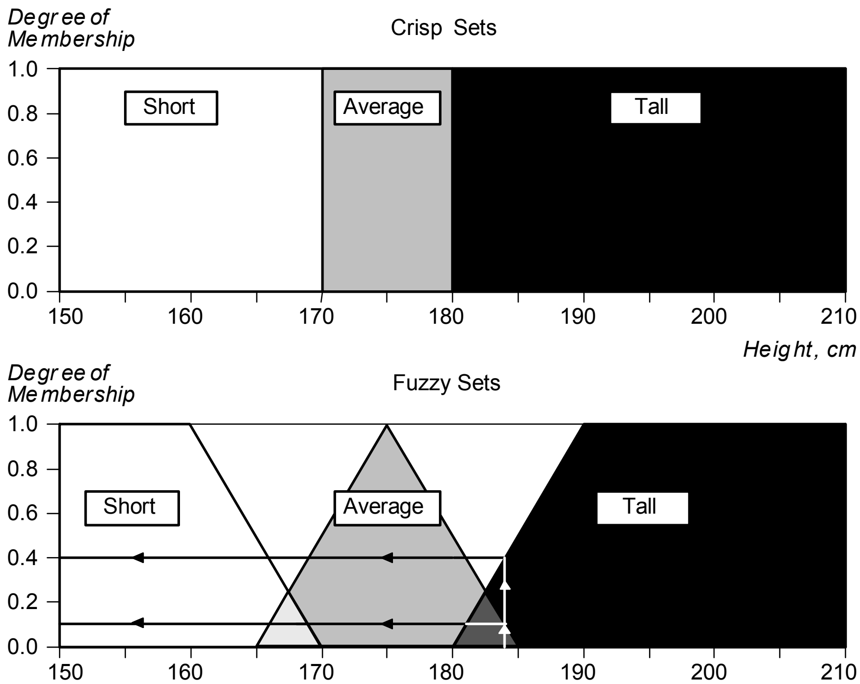


Fig. 3.2 Crisp and fuzzy sets of short, average and tall men [35]

3.1.2 Types of membership functions

There are various types if membership functions in fuzzy logic system [36]. The membership functions are given below.

- S-shaped function
- Z-shaped function
- Triangular membership function
- Trapezoidal membership function
- Gaussian distribution function
- Pi function
- Vicinity function

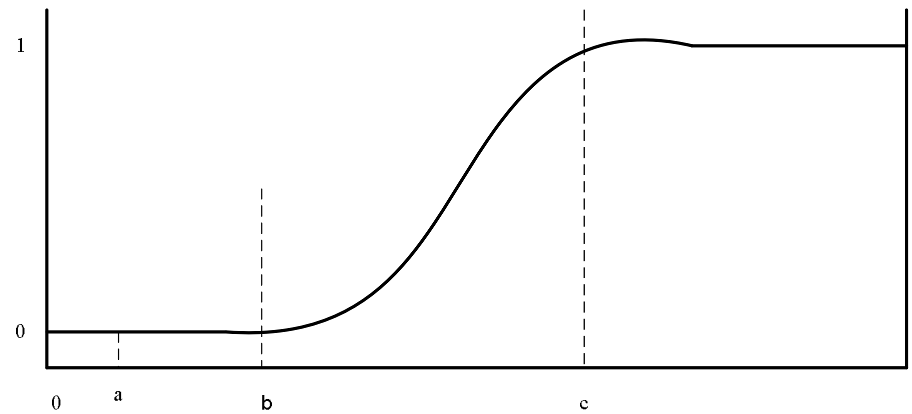


Fig. 3.3 S-shaped function

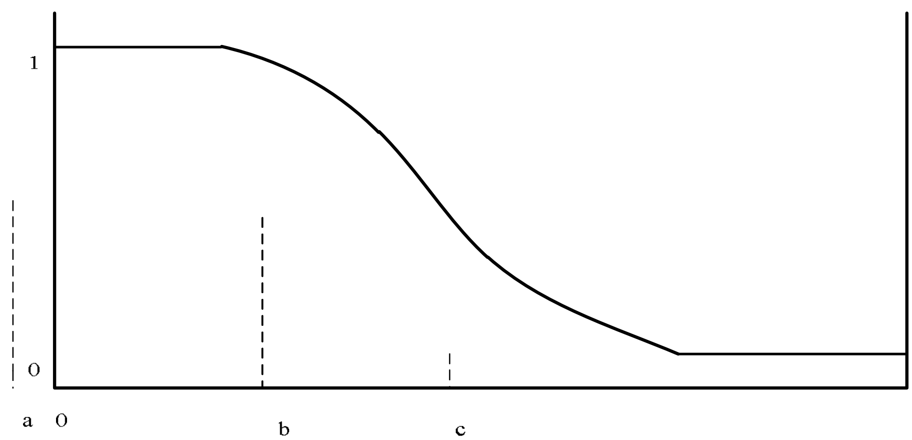


Fig. 3.4 Z-shaped function

S-shaped function: Fig. 3.3 shows the graphical representation of S-shaped function. This spline-based curve is a mapping on the vector x, and is named because of its S-shape. The parameters b and c locate the extremes of the sloped portion of the curve.

Z-shaped function: Fig. 3.4 shows the graphical representation of Z-shaped function. It represents an asymmetrical polynomial curve open to the left. This spline-based function of x is so named because of its Z-shape. The parameters b and c locate the extremes of the sloped portion of the curve.

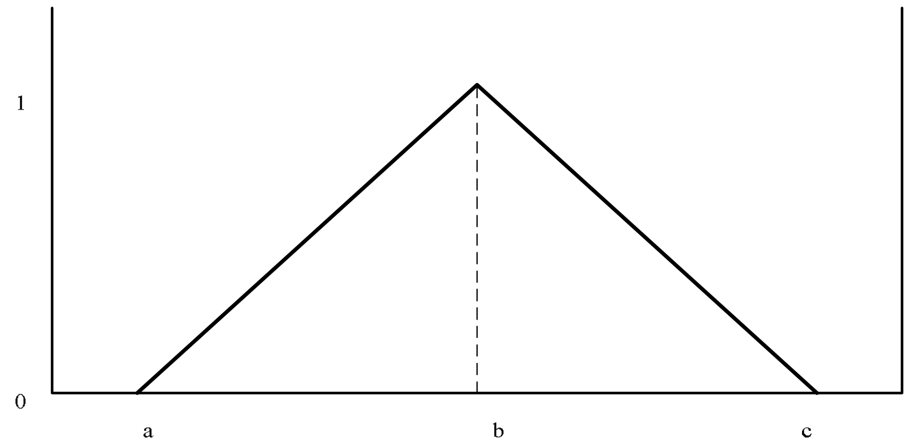


Fig. 3.5 Triangular membership function

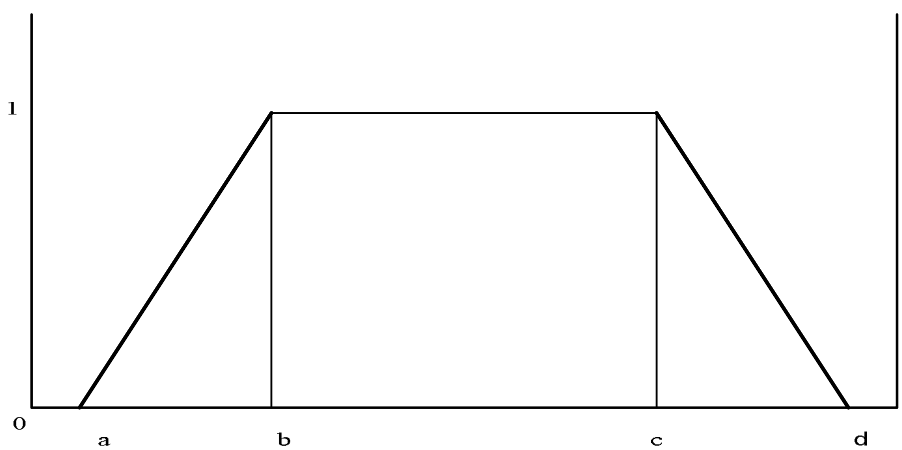


Fig. 3.6 Trapezoidal membership function

Triangular membership function: Fig. 3.5 shows the graphical representation of Triangular membership function. The Triangular MF block implements a Triangular-shaped membership function. The parameters a and c set the left and right "feet," or base points, of the triangle. The parameter b sets the location of the triangle peak.

Trapezoidal membership function: Fig. 3.6 shows the graphical representation of Trapezoidal membership function. The Trapezoidal curve is a function of a vector, x, and depends on four scalar parameters *a*, *b*, *c*, and *d*, as given by the parameters *a* and *d* locate the "feet" of the Trapezoid and the parameters *b* and *c* locate the "shoulders."

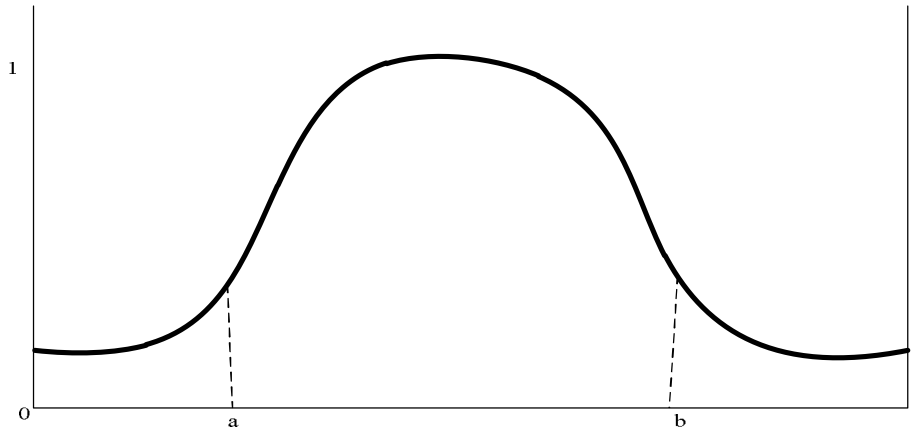


Fig. 3.7 Gaussian distribution function

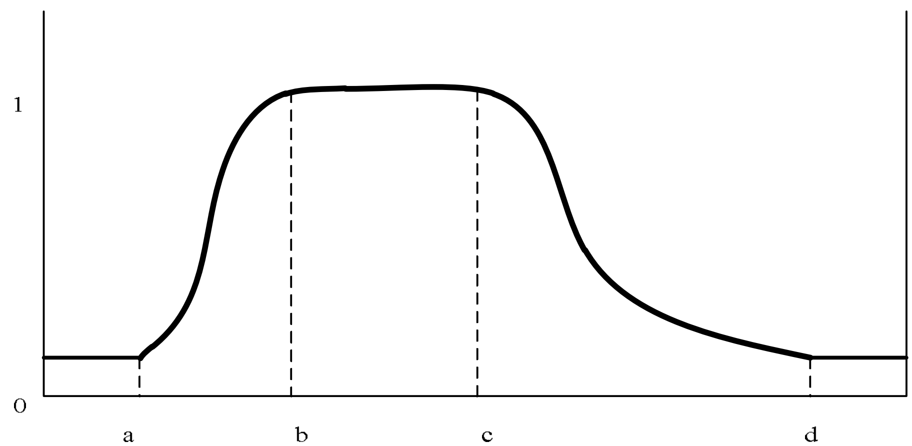


Fig. 3.8 Pi function

Gaussian distribution function: Fig. 3.7 shows the graphical representation of Gaussian distribution function. It depends on two parameters. It is very important in fuzzy logic system. Two membership functions are built on the Gaussian distribution curve, a simple Gaussian curve and a two-sided composite of two different Gaussian curves. The two functions are gaussmf and gauss2mf.

Pi Function: Fig. 3.8 shows the graphical representation of Pi function. The Pi-shaped curve is a spine-based curve which is named so. The membership function is evaluated at the points determined by the vector x. The parameters *a* and *d* locate the "feet" of the curve, while *b* and *c* locate its "shoulders.

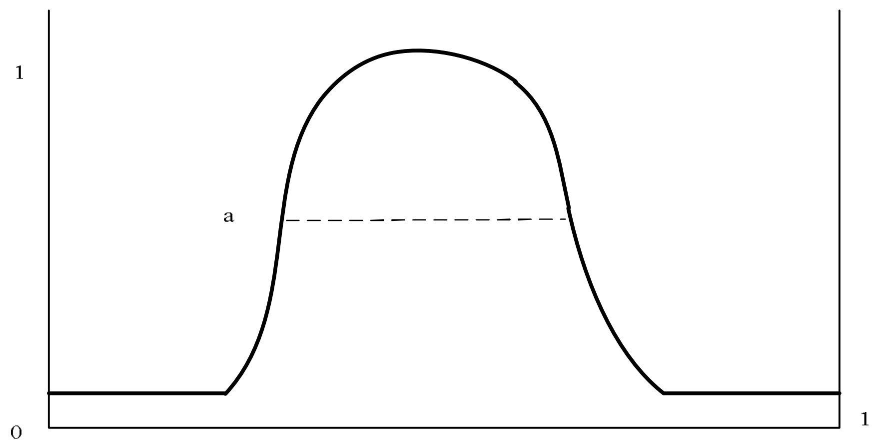


Fig. 3.9 Vicinity function

Vicinity function: Fig. 3.9 shows the graphical representation of Vicinity function. This is also called π function. Here 'a' is called bandwidth.

3.1.3 Operations of fuzzy sets

The classical set theory developed in the late 19^{th} century by Georg Cantor describes how crisp sets can interact. These interactions are called operations. Fig. 3.10 shows the Cantor's sets used in fuzzy logic system.

- **Complement:** The complement of a set is an opposite of this set. For example, if we have the set of tall men, its complement is the set of NOT tall men. When we remove the tall men set from the universe of discourse, we obtain the complement. If A is the fuzzy set, its complement $Ø_A$ can be found as follows:

$$m\phi_A(x) = 1 - m_A(x)m \tag{7}$$

- **Containment:** Similar to a Chinese box, a set can contain other sets. The smaller set is called the subset. For example, the set of tall men contains all tall men; very tall men are a subset of tall men. However, the tall men set is just a subset of the set of men. In crisp sets, all elements of a subset entirely belong to a larger set. In fuzzy sets, however, each element can belong less to the subset than to the larger set. Elements of the fuzzy subset have smaller memberships than in the larger set.

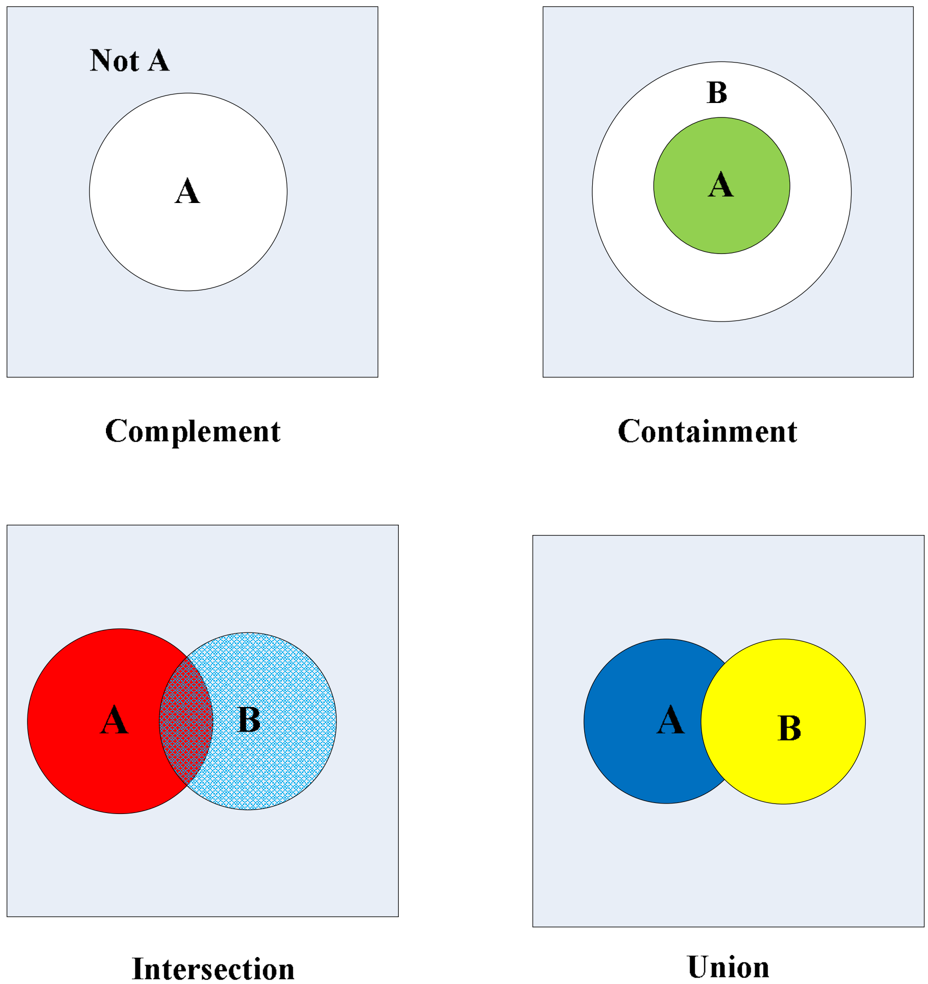


Fig. 3.10 Cantor's sets

- **Intersection:** In classical set theory, an intersection between two sets contains the elements shared by these sets. For example, the intersection of the set of tall men and the set of fat men is the area where these sets overlap. In fuzzy sets, an element may partly belong to both sets with different memberships. A fuzzy intersection is the lower membership in both sets of each element. The fuzzy intersection of two fuzzy sets A and B on universe of discourse X:

$$m_A C_B(x) = \min\left[m_A(x), m_B(x)\right] = m_A(x) C m_B(x) \quad (8)$$

- **Union:** The union of two crisp sets consists of every element that falls into either set. For example, the union of tall men and fat men contains all men who are tall or fat. In fuzzy sets, the union is the reverse of the intersection. That is, the union is the largest membership value of the element in either set. The fuzzy operation for forming

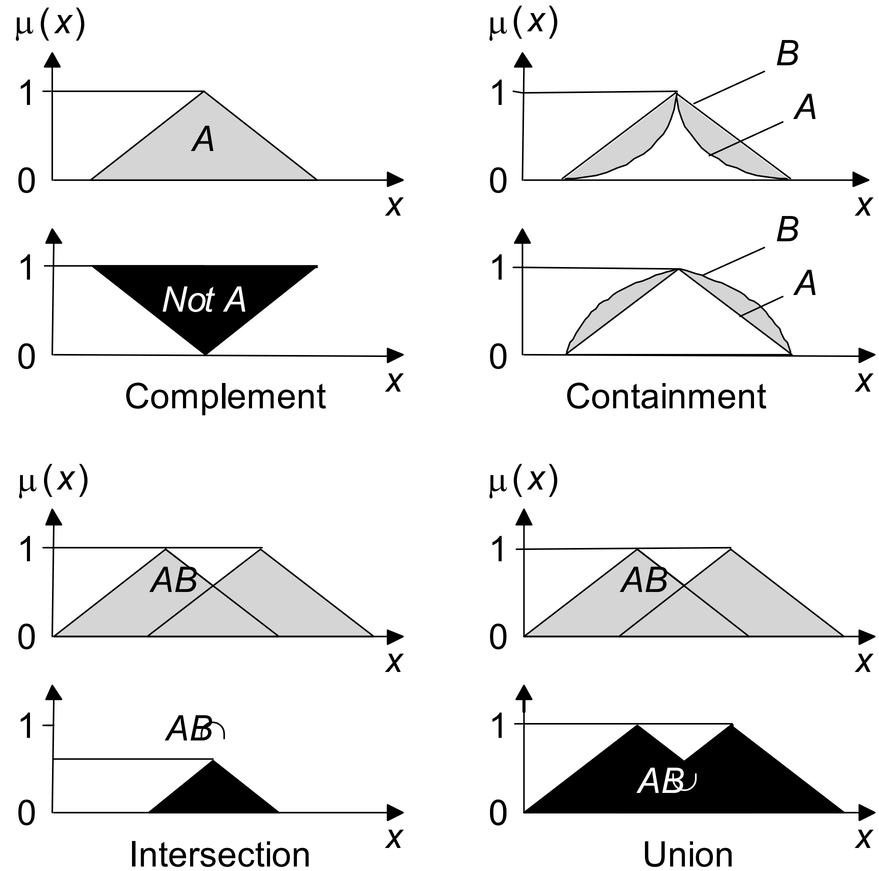


Fig. 3.11 Operations of fuzzy sets [34]

the union of two fuzzy sets A and B on universe X can be given as and Fig. 3.11 show operations of fuzzy sets.

$$m_A E_B(x) = \max[m_A(x), m_B(x)] = m_A(x) E m_B(x) \tag{9}$$

3.1.4: Fuzzy rules: In 1973, LotfiZadeh published his second most influential paper. This paper outlined a new approach to analysis of complex systems, in which Zadeh suggested capturing human knowledge in fuzzy rules. A fuzzy rule can be defined as a conditional statement in the form:

$$\begin{array}{l} IF\ x\ is\ A \\ THEN\ y\ is\ B \end{array} \tag{10}$$

where x and y are linguistic variables; and A and B are linguistic values determined by fuzzy sets on the universe of discourses X and Y, respectively.

3.2 Fuzzy inference

The most commonly used fuzzy inference technique is the so-called Mamdani method. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination. He applied a set of fuzzy rules supplied by experienced human operators. Mamdani method is widely accepted for capturing expert knowledge [28], [37]. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type fuzzy inference entails a substantial computational burden. On the other hand, Sugeno method is computationally effective and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic nonlinear systems.

3.2.1 Mamdani fuzzy inference: The Mamdani-style fuzzy inference process is performed in four steps:

a. Fuzzification of the input variables,

b. Rule evaluation;

c. Aggregation of the rule outputs, and finally

d. Defuzzification.

3.2.2 Sugeno fuzzy inference

Mamdani-style inference, as we have just seen, requires us to find the cancroids of a two-dimensional shape by integrating across a continuously varying function. In general, this process is not computationally efficient. Michio Sugeno suggested to use a single spike, a singleton, as the membership function of the rule consequent. A singleton, or more precisely a fuzzy singleton, is a fuzzy set with a membership function that is united at a single particular point on the universe of discourse and zero everywhere else.

Sugeno-style fuzzy inference is very similar to the Mamdani method. Sugeno changed only a rule consequent. Instead of a fuzzy set, he used a mathematical function of the output variable. The format of the Sugeno-style fuzzy rule is

$$
\begin{aligned}
&IF\ x\ is\ A \\
&AND\ y\ is\ B \\
&THEN\ z\ is\ f(x, y)
\end{aligned}
\tag{11}
$$

where x, y and z are linguistic variables; A and B are fuzzy sets on universe of discourses X and Y, respectively; and $f(x, y)$ is a mathematical function.

Chapter 4

Service Based Handover Decision Using Fuzzy Logic

Service is an important factor for the users and particular services require respective QoS level. There are different types of service existing in heterogeneous wireless networks such as voice, video, data, video conference, VoIP calls, and so on. In this research we select a network which is suited for particular service and we use fuzzy logic for network selection. Some important parameters of the network are inputs of fuzzy logic. However, by considering all factors proper network is selected by handover process between macrocell and femtocell then handover is executed.

4.1 Scenarios of system model

In this research, we consider two scenarios of the system models. The first scenario is shown in Fig. 4.1 in which the MS is situated inside macrocell and handover occurs either to target femtocell network or remains in the macrocell. The second scenario is shown in Fig. 4.2 in which the MS is situated inside the femtocell. There are two options possible for this case where handover occurs either from the femtocell to femtocell or femtocell to macrocell.

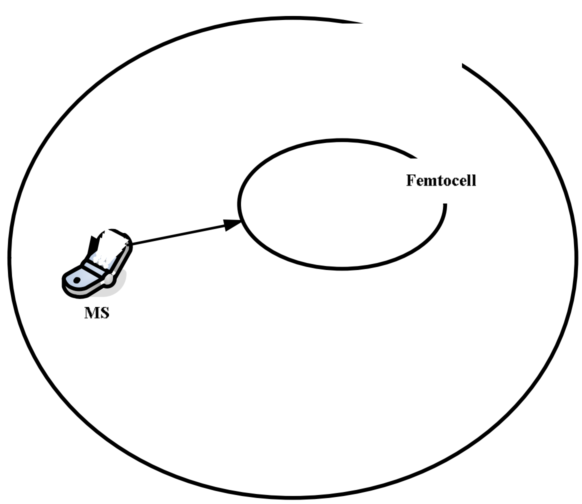


Fig. 4.1 Case-1 handover scenario in macrocell/femtocell integrated network

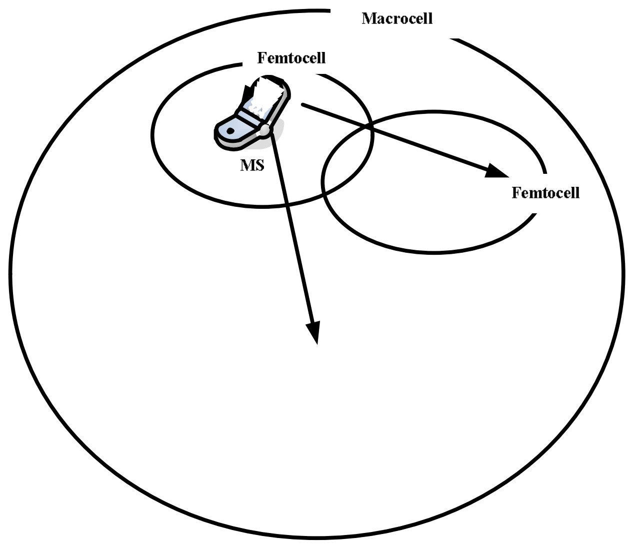


Fig. 4.2 Case-2 handover scenario in macrocell/femtocell integrated network

We also consider three service types such as voice, video, and data for calculating handover factor. The availability of the network space is indicated by RSSI level. Data rate is considered by the available throughput of both networks. Velocity is indicated by user's mobility in which MS travels in the network boundary. Interference considers the quality of signal level and noise level which user achieved from both macrocell and femtocell networks.

4.2 Call flow of system model

Fig. 4.3 shows the basic call flow for case-1 scenario of the system model**.** The MS measures RSSI of a macro base station. In our proposed model we consider two networks one is femtocell and another is macrocell. First, the system detects the service type the mobile user required to execute then after detecting the service type the system collects the input as RSSI, data rate, velocity, and interference level (SNIR). All inputs are combined to feed for the fuzzy logic system for processing the mechanism of handover factor. Here Γ is the threshold factor value to make handover decision to femtocell network. Γ_m is the calculated handover factor of macrocell. If the handover factor is greater or equal to threshold factor Γ then MS initiates handover to target femtocell networks otherwise if not then MS goes to next condition that if handover factor is greater or equal to Γ_m then handover to femtocell otherwise MS remains in the current macrocell network.

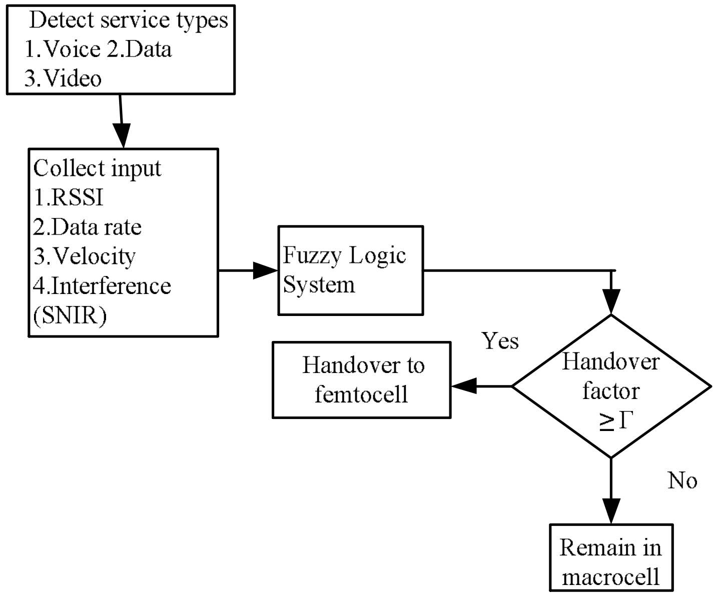


Fig. 4.3 System model for case-1 handover decision.

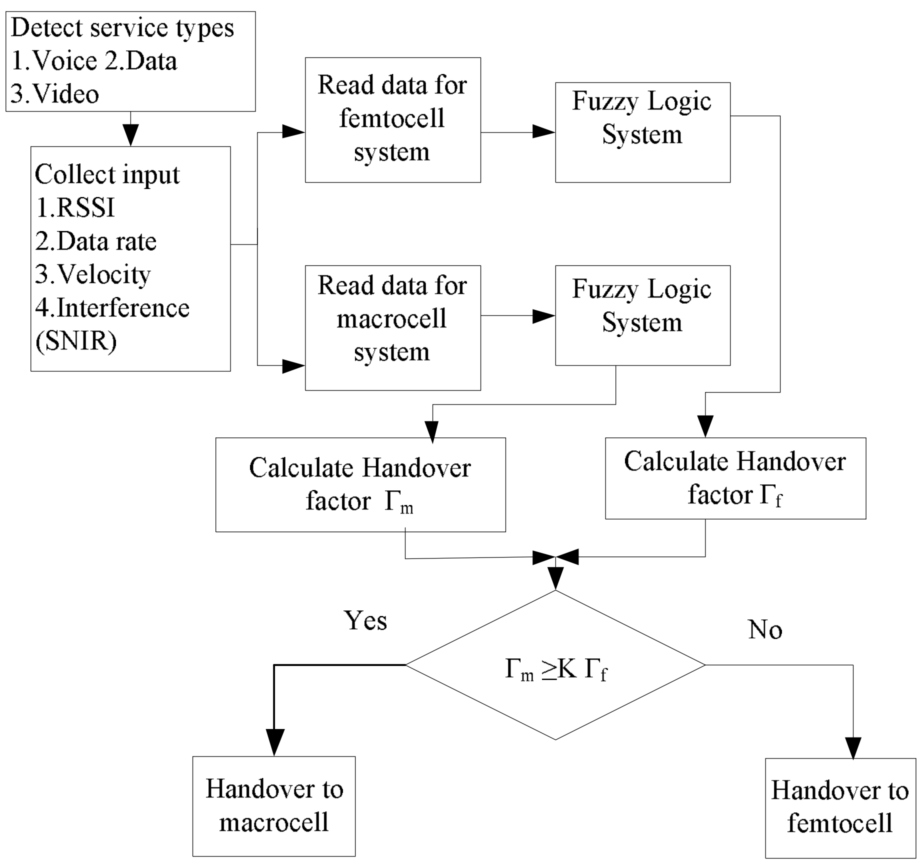


Fig. 4.4 System model for case-2 handover decision.

Fig. 4.4 shows the basic call flow for case-2 scenario of the system model. Γ_f is the calculated handover factor for target femtocell. Firstly the system feeds the input parameters based on service type to fuzzy sub-system. Then it calculates the handover factors for two different target networks, one is for femtocell network and another for macrocell network. After calculating two handover factors, it makes a decision by comparing two different handover factors. We add a weight value K with femtocell's handover factor. If the value of K increases then the preference for femtocell networks will increases for handover. Therefore, the operator has the control to change the preference of macrocell or femtocell networks on the basis of requirement. If Γ_m is not larger than Γ_f then it decides for handover to femtocell network otherwise, it goes for the next condition. Here if $K\Gamma_f$ is larger or equal to Γ_m then it decides for handover to femtocell also otherwise it makes handover to macrocell network. Finally, decision to handover will be successfully accomplished in our system model.

4.3 Controller of handover decision

The basic architecture of a fuzzy logic system is shown in Fig. 4.5. It consists of four components fuzzifier, knowledge-based IF-THEN rules, fuzzy inference system (FIS) and defuzzifier. A fuzzy logic inference system can implement in the MS as a handover initiation engine to provide rules for decision making. We use a Mamdani Fuzzy inference system (FIS) that is composed of the functional blocks. A Fuzzifier transforms the crips inputs into degrees of the functional blocks. A Fuzzy rule base contains a number of fuzzy IF-THEN rules. A Data base defines the membership functions of the fuzzy sets used in the fuzzy rules. A FIS performs the inference operators on the fuzzy rules. A Defizzifier transforms the fuzzy results of the inference into a crips output. Each of the fuzzy sets has four inputs (RSSI, data

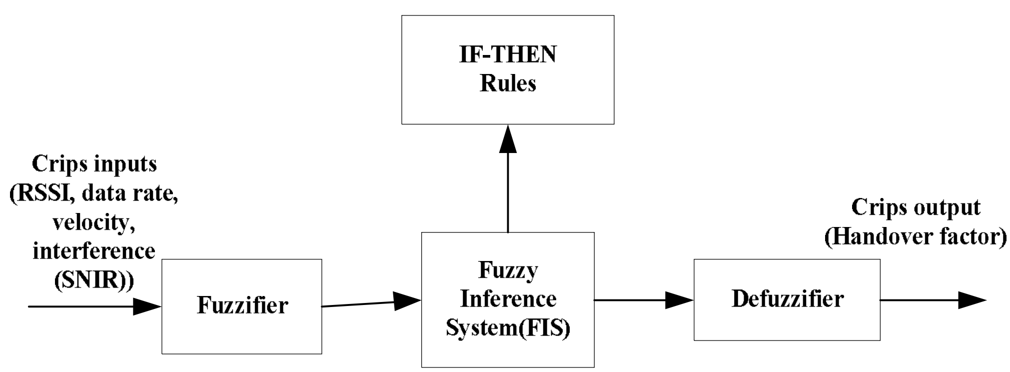
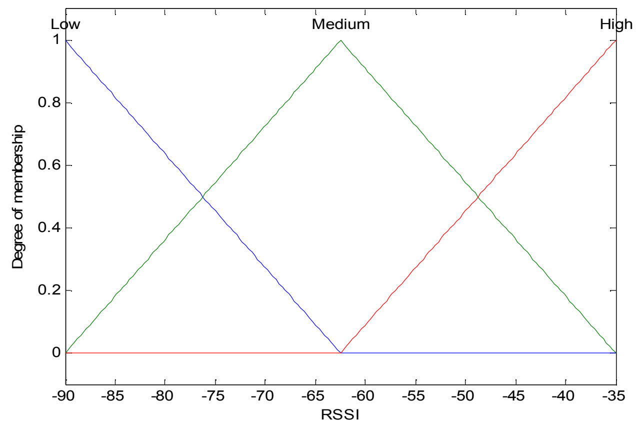


Fig. 4.5 Architecture of Fuzzy logic system.

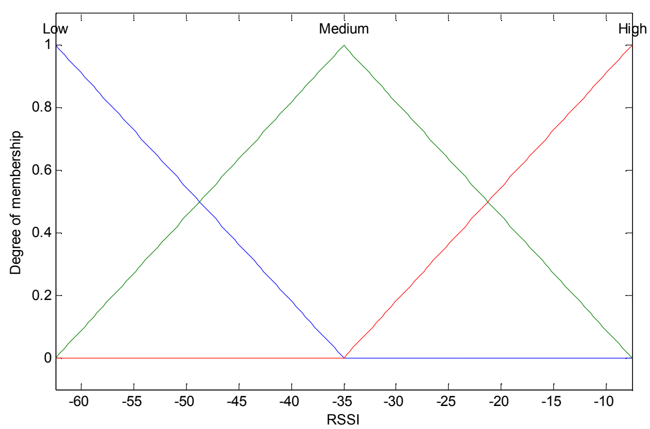
rate, velocity, and SNIR) and three membership functions Low, Medium, and High. Here we choose Triangular Membership Function (MF) for simple, smooth, and absolute value at all.

Figs. 4.6-4.9 show the MF of the networks input parameters as (a) User's RSSI considering macrocell for voice and video service ,(b)User's data rate considering macrocell for voice and video service, (c) User velocity considering macorcell for voice and viceo service, and (d) User's inerference level (SNIR) considering macrocell for voice and video service.

Fig. 4.6 shows the Membership function of the inputs considering user's RSSI in macrocell network (a) for voice service and (b) for video service. The range of user's RSSI of macrocell for voice service is -95dBm to -35dBm and for video service is -62.5dBm to -7.5dBm. The Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of RSSI and y-axis defines the degree of membership which range is from 0 to 1 for macrocell network.



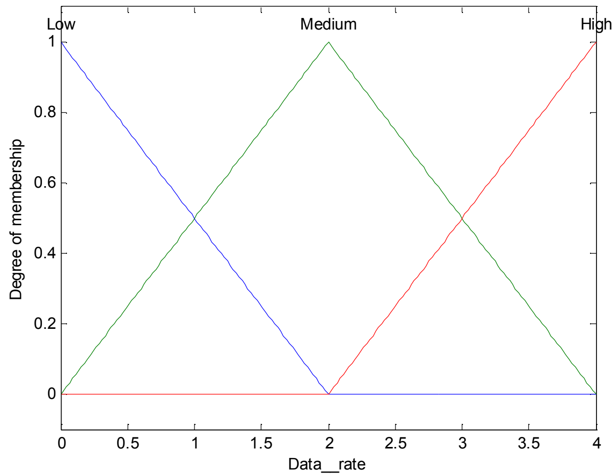
(a)



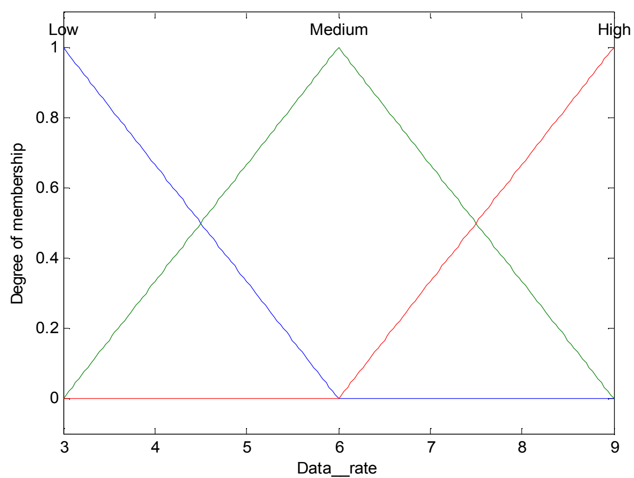
(b)

Fig. 4.6 Membership function of the inputs considering user's RSSI in macrocell network (a) for voice service (b) for video service

Fig. 4.7 shows the Membership function of the inputs considering user's data rate in macrocell network (a) for voice service and (b) for video service. The range of user's data rate of macrocell for voice service is 0 Mbps to 4 Mbps and for video service is 3 Mbps to 9 Mbps. The Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of data rate and y-axis defines the degree of membership which range is from 0 to 1 for macrocell network.



(a)



(b)

Fig. 4.7 Membership function of the inputs considering user's achievable data rate in macrocell network (a) for voice service (b) for video service

Fig. 4.8 shows the Membership function of the inputs considering user velocity in macrocell network for both voice and video services. The range of user velocity of macrocell for voice and video service is 0 km/hr to 20 km/hr and the Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of velocity and y-axis defines the degree of membership which range is from 0 to 1 for macrocell network.

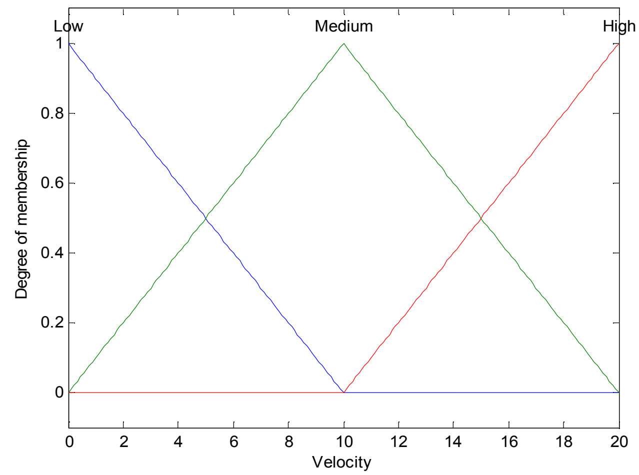
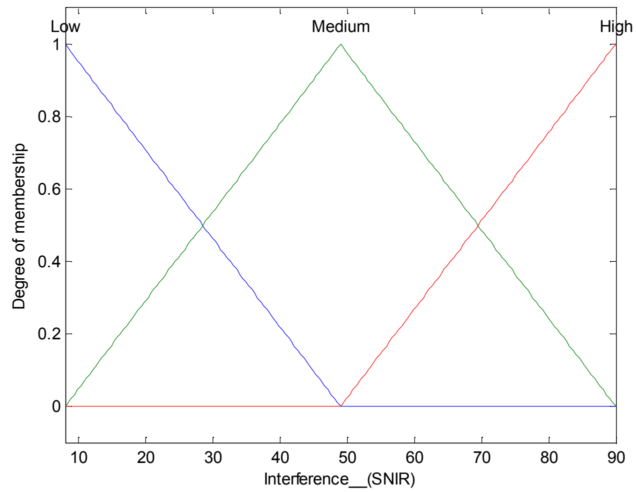
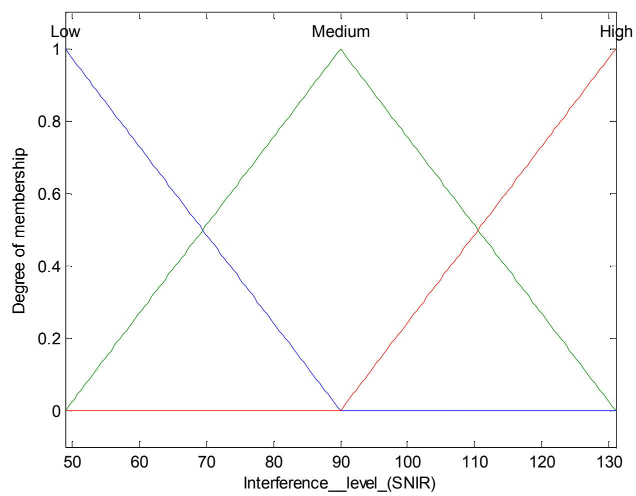


Fig. 4.8 Membership function of the inputs considering user velocity in macrocell network both voice and video services

Fig. 4.9 shows the Membership function of the inputs considering user's interference level (SNIR) in macrocell network (a) for voice service and (b) for video service. The range of user's interference level (SNIR) of macrocell for voice service is 08dB to 90dB and for video service is 49dB to 131dB. The Triangular MF is devided by three levels like Low, Medium, and High. The x-axis defines the range of data rate and y-axis defines the degree of membership which is range from 0 to 1 for macrocell network.



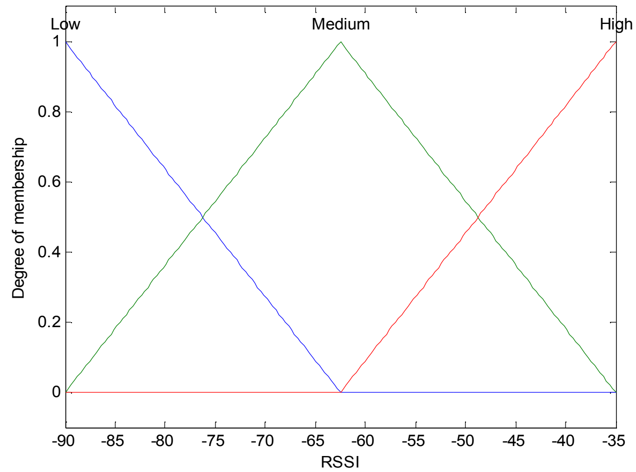
(a)



(b)

Fig. 4.9 Membership function of the inputs considering user received interference level (SNIR) in macrocell network (a) for voice service (b) for video service

Figs. 4.10-4.13 show the MF of the networks input parameters as (a) User's RSSI considering femtocell for voice and video service ,(b)User's data rate considering femtocell for voice and video service, (c) User velocity considering femtocell for voice and video service, and (d) User's inerference level (SNIR) considering femtocell for voice and video service.



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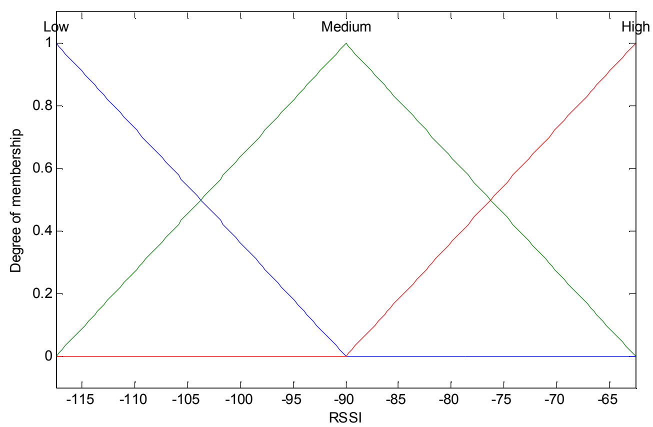
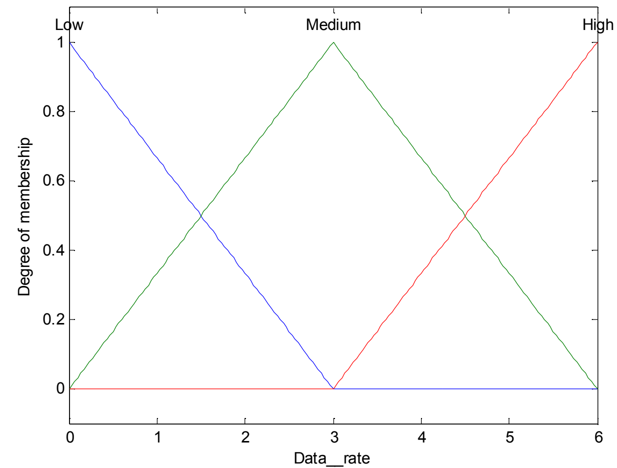


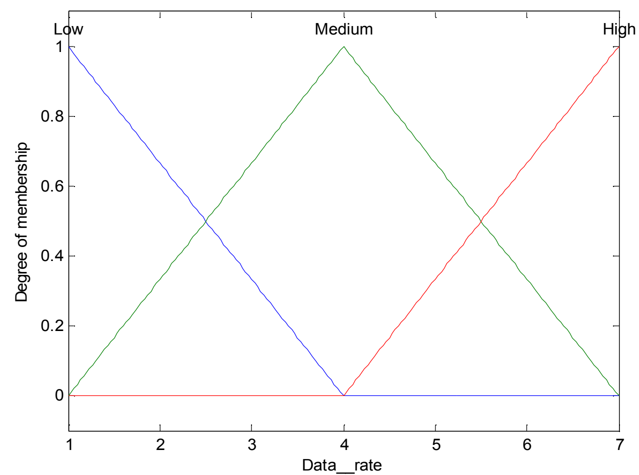
(b)

Fig. 4.10 Membership function of the inputs considering user's RSSI in femtocell network (a) for voice service (b) for video service

Fig. 4.10 shows the Membership function of the inputs considering user's RSSI in femtocell network (a) for voice service and (b) for video service. The range of user's RSSI of femtocell for voice service is -95dBm to -35dBm and for video service is -117.5dBm to -62.5dBm. The Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of RSSI and y-axis defines the degree of membership which range is from 0 to 1 for femtocell network.



(a)



(b)

Fig. 4.11 Membership function of the inputs considering user's achievable data rate in femtocell network (a) for voice service (b) for video service

Fig. 4.11 shows the Membership function of the inputs considering user's data rate in femtocell network (a) for voice service and (b) for video service. The range of user's data rate of femtocell for voice service is 0 Mbps to 6 Mbps and for video service is 1 Mbps to 7 Mbps. The Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of data rate and y-axis defines the degree of membership which range is from 0 to 1 for femtocell network.

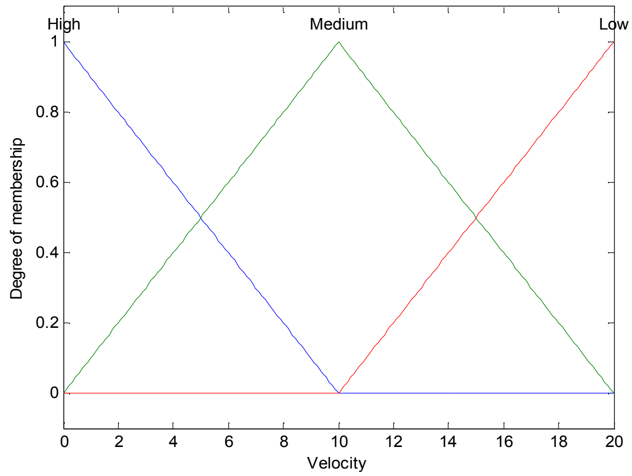
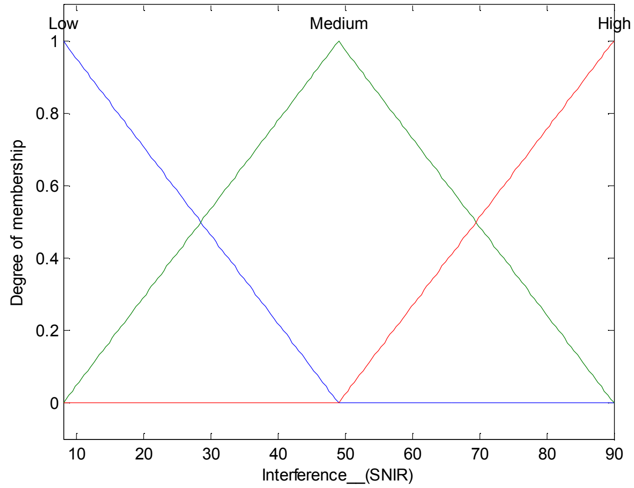
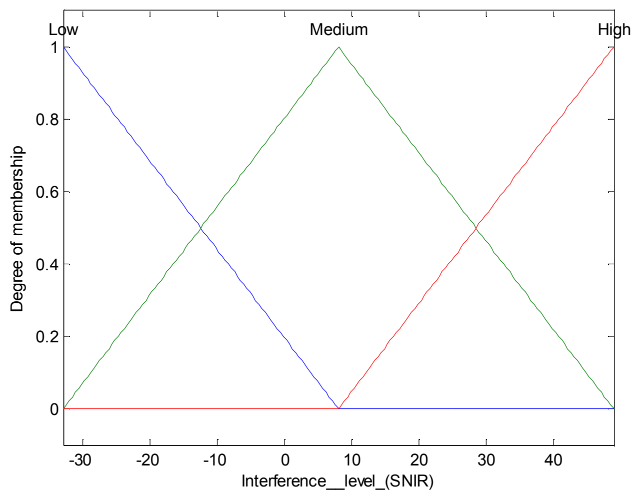


Fig. 4.12 Membership function of the inputs considering user velocity in femtocell network for both voice and video services

Fig. 4.12 shows the Membership function of the inputs considering user velocity in femtocell network (a) for voice service and (b) for video service. The range of user velocity of femtocell for voice and video service is 0 km/hr to 20 km/hr and the Triangular MF is devided by three levels such as Low, Medium, and High. The x-axis defines the range of velocity and y-axis defines the degree of membership which range is from 0 to 1 for femtocell network.



(a)



(b)

Fig. 4.13 Membership function of the inputs considering user received interference level (SNIR) in femtocell network (a) for voice service (b) for video service

Fig. 4.13 shows the Membership function of the inputs considering user's interference level (SNIR) in femtocell network (a) for voice service and (b) for video service. The range of user's interference level (SNIR) of femtocell for voice service is 08dB to 90dB and for video service is -33dB to 49dB. The Triangular MF is devided by three levels like Low, Medium, and High. The x-axis defines the range of data rate and y-axis defines the degree of membership which is range from 0 to 1 for femtocell network.

Table 4.1 Ranges of inputs (voice user)

Inputs	Low	High	Units
RSSI (macro and femto)	-90	-35	dBm
Data rate (macro)	0	4	Mbps
Data rate (femto)	0	6	Mbps
Velocity (macro)	0	20	km/hr
Velocity (femto)	20	0	km/hr
Interference level (SNIR) (macro and femto)	8	90	dB

Table 4.1 shows the inputs for voice users for both macrocell and femtocell networks. The ranges of inputs for fuzzy variables RSSI, data rate, velocity, and interference level (SNIR) are also shown in Table 4.1. Table 4.2 shows the inputs for video user for both macrocell and femtocell networks. The ranges of inputs for fuzzy variables RSSI, data rate, velocity, and interference level (SNIR) are also shown in Table 4.2. The Membership function of voice and video service are shown in graphically

Table 4.2 Ranges of inputs (video user)

Inputs	Low	High	Units
RSSI (macro)	-62.5	-7.5	dBm
Data rate (macro)	3	9	Mbps
Velocity (macro)	0	20	km/hr
Interference level (SNIR) (macro)	49	131	dB
RSSI (femto)	-117.5	-62.5	dBm
Data rate (femto)	1	7	Mbps
Velocity (femto)	20	0	km/hr
Interference level (SNIR) (femto)	-33	49	dB

Fig. 4.14 shows the membership function of handover factor for (a) voice service and (b) video service. It is divided into six categories such as Lower, Low, Lower medium, Higher medium, High, and Higher levels. The x-axis defines the handover factor and y-axis defines the degree of membership .The Fuzzy system has rules base that contains IF-THEN rules, which required by the fuzzy inference system. There are several antecedents that are combined using fuzzy operators such as AND, OR, and NOT. Here we designed four fuzzy inputs variables and three fuzzy sets for each fuzzy variable, hence, the maximum possible number of rules in our rule base is 3^4 =81.The fuzzy output decision sets are arranged into a single fuzzy set and passed through the defuzzifier to be converted into precise quantity, the handover factor, which determines whether a handover is necessary or not as still remain the same network. The range of handover factor is from 0 to 1 which is a Gaussian function shown in Fig. 4.14. The maximum membership of the sets is Lower and Higher at 0 or 1 respectively. Fig. 4.3 shows 81 IF-THEN rules of fuzzy logic system.

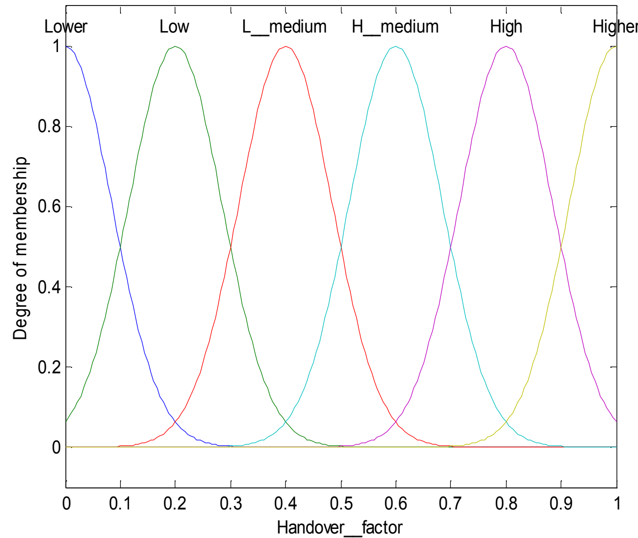


Fig. 4.14 Memberships function of handover factor

Table 4.3 Fuzzy 81 IF-THEN rules

No of rules	Rules
Rule-1	If RSSI is low and Data rate is low and Velocity is low and Interference level (SNIR) is low then handover factor is lower
Rule-2	If RSSI is low and Data rate is low and Velocity is low and Interference level (SNIR) is medium then handover factor is lower
Rule-3	If RSSI is low and Data rate is low and Velocity is low and Interference level (SNIR) is high then handover factor is low
Rule-4	If RSSI is low and Data rate is low and Velocity is medium and Interference level (SNIR) is low then handover factor is lower
Rule-5	If RSSI is low and Data rate is low and Velocity is medium and Interference level (SNIR) is medium then handover factor is low
Rule-6	If RSSI is low and Data rate is low and Velocity is medium and Interference level (SNIR) is high then handover factor is lower medium
Rule-7	If RSSI is low and Data rate is low and Velocity is high and Interference level (SNIR) is low then handover factor is low

Rule-8	If RSSI is low and Data rate is low and Velocity is high and Interference level (SNIR) is medium then handover factor is lower medium
Rule-9	If RSSI is low and Data rate is low and Velocity is high and Interference level (SNIR) is high then handover factor is lower medium
Rule-10	If RSSI is low and Data rate is medium and Velocity is low and Interference level (SNIR) is low then handover factor is lower
Rule-11	If RSSI is low and Data rate is medium and Velocity is low and Interference level (SNIR) is medium then handover factor is low
Rule-12	If RSSI is low and Data rate is medium and Velocity is low and Interference level (SNIR) is high then handover factor is lower medium
Rule-13	If RSSI is low and Data rate is medium and Velocity is medium and Interference level (SNIR) is low then handover factor is low
Rule-14	If RSSI is low and Data rate is medium and Velocity is medium and Interference level (SNIR) is medium then handover factor is lower medium
Rule-15	If RSSI is low and Data rate is medium and Velocity is medium and Interference level (SNIR) is high then handover factor is lower medium
Rule-16	If RSSI is low and Data rate is medium and Velocity is high and Interference level (SNIR) is low then handover factor is lower medium
Rule-17	If RSSI is low and Data rate is medium and Velocity is high and Interference level (SNIR) is medium then handover factor is lower medium
Rule-18	If RSSI is low and Data rate is medium and Velocity is high and Interference level (SNIR) is high then handover factor is higher medium
Rule-19	If RSSI is low and Data rate is high and Velocity is low and Interference level (SNIR) is low then handover factor is low
Rule-20	If RSSI is low and Data rate is high and Velocity is low and Interference level (SNIR) is medium then handover factor is lower medium
Rule-21	If RSSI is low and Data rate is high and Velocity is low and Interference

	level (SNIR) is high then handover factor is lower medium
Rule-22	If RSSI is low and Data rate is high and Velocity is medium and Interference level (SNIR) is low then handover factor is lower medium
Rule-23	If RSSI is low and Data rate is high and Velocity is medium and Interference level (SNIR) is medium then handover factor is lower medium
Rule-24	If RSSI is low and Data rate is high and Velocity is medium and Interference level (SNIR) is high then handover factor is higher medium
Rule-25	If RSSI is low and Data rate is high and Velocity is high and Interference level (SNIR) is low then handover factor is lower medium
Rule-26	If RSSI is low and Data rate is high and Velocity is high and Interference level (SNIR) is medium then handover factor is higher medium
Rule-27	If RSSI is low and Data rate is high and Velocity is high and Interference level (SNIR) is high then handover factor is high
Rule-28	If RSSI is medium and Data rate is low and Velocity is low and Interference level (SNIR) is low then handover factor is lower
Rule-29	If RSSI is medium and Data rate is low and Velocity is low and Interference level (SNIR) is medium then handover factor is low
Rule-30	If RSSI is medium and Data rate is low and Velocity is low and Interference level (SNIR) is high then handover factor is lower medium
Rule-31	If RSSI is medium and Data rate is low and Velocity is medium and Interference level (SNIR) is low then handover factor is low
Rule-32	If RSSI is medium and Data rate is low and Velocity is medium and Interference level (SNIR) is medium then handover factor is lower medium
Rule-33	If RSSI is medium and Data rate is low and Velocity is medium and Interference level (SNIR) is high then handover factor is lower medium
Rule-34	If RSSI is medium and Data rate is low and Velocity is high and Interference level (SNIR) is low then handover factor is lower medium

Rule-35	If RSSI is medium and Data rate is low and Velocity is high and Interference level (SNIR) is medium then handover factor is lower medium
Rule-36	If RSSI is low and Data rate is low and Velocity is low and Interference level (SNIR) is low then handover factor is higher medium
Rule-37	If RSSI is medium and Data rate is medium and Velocity is low and Interference level (SNIR) is low then handover factor is low
Rule-38	If RSSI is medium and Data rate is medium and Velocity is low and Interference level (SNIR) is medium then handover factor is lower medium
Rule-39	If RSSI is medium and Data rate is medium and Velocity is low and Interference level (SNIR) is high then handover factor is lower medium
Rule-40	If RSSI is medium and Data rate is medium and Velocity is medium and Interference level (SNIR) is low then handover factor is lower medium
Rule-41	If RSSI is medium and Data rate is medium and Velocity is medium and Interference level (SNIR) is medium then handover factor is lower medium
Rule-42	If RSSI is medium and Data rate is medium and Velocity is medium and Interference level (SNIR) is high then handover factor is higher medium
Rule-43	If RSSI is medium and Data rate is medium and Velocity is high and Interference level (SNIR) is low then handover factor is lower medium
Rule-44	If RSSI is medium and Data rate is medium and Velocity is high and Interference level (SNIR) is medium then handover factor is higher medium
Rule-45	If RSSI is medium and Data rate is medium and Velocity is high and Interference level (SNIR) is high then handover factor is high
Rule-46	If RSSI is medium and Data rate is high and Velocity is low and Interference level (SNIR) is low then handover factor is lower medium
Rule-47	If RSSI is medium and Data rate is high and Velocity is low and

	Interference level (SNIR) is medium then handover factor is lower medium
Rule-48	If RSSI is medium and Data rate is high and Velocity is low and Interference level (SNIR) is high then handover factor is higher medium
Rule-49	If RSSI is medium and Data rate is high and Velocity is medium and Interference level (SNIR) is low then handover factor is lower medium
Rule-50	If RSSI is medium and Data rate is high and Velocity is medium and Interference level (SNIR) is medium then handover factor is high
Rule-51	If RSSI is medium and Data rate is high and Velocity is medium and Interference level (SNIR) is high then handover factor is high
Rule-52	If RSSI is medium and Data rate is high and Velocity is high and Interference level (SNIR) is low then handover factor is higher medium
Rule-53	If RSSI is medium and Data rate is high and Velocity is high and Interference level (SNIR) is medium then handover factor is high
Rule-54	If RSSI is medium and Data rate is high and Velocity is high and Interference level (SNIR) is high then handover factor is high
Rule-55	If RSSI is high and Data rate is low and Velocity is low and Interference level (SNIR) is low then handover factor is low
Rule-56	If RSSI is high and Data rate is low and Velocity is low and Interference level (SNIR) is medium then handover factor is lower medium
Rule-57	If RSSI is high and Data rate is low and Velocity is low and Interference level (SNIR) is high then handover factor is lower medium
Rule-58	If RSSI is high and Data rate is low and Velocity is medium and Interference level (SNIR) is low then handover factor is lower medium
Rule-59	If RSSI is high and Data rate is low and Velocity is medium and Interference level (SNIR) is medium then handover factor is lower medium
Rule-60	If RSSI is high and Data rate is low and Velocity is medium and Interference level (SNIR) is high then handover factor is higher medium

Rule-61	If RSSI is high and Data rate is low and Velocity is high and Interference level (SNIR) is low then handover factor is lower medium
Rule-62	If RSSI is high and Data rate is low and Velocity is high and Interference level (SNIR) is medium then handover factor is higher medium
Rule-63	If RSSI is high and Data rate is low and Velocity is high and Interference level (SNIR) is high then handover factor is high
Rule-64	If RSSI is high and Data rate is medium and Velocity is low and Interference level (SNIR) is low then handover factor is lower medium
Rule-65	If RSSI is high and Data rate is medium and Velocity is low and Interference level (SNIR) is medium then handover factor is lower medium
Rule-66	If RSSI is high and Data rate is medium and Velocity is low and Interference level (SNIR) is high then handover factor is higher medium
Rule-67	If RSSI is high and Data rate is medium and Velocity is medium and Interference level (SNIR) is low then handover factor is lower medium
Rule-68	If RSSI is high and Data rate is medium and Velocity is medium and Interference level (SNIR) is medium then handover factor is higher medium
Rule-69	If RSSI is high and Data rate is medium and Velocity is medium and Interference level (SNIR) is high then handover factor is high
Rule-70	If RSSI is high and Data rate is medium and Velocity is high and Interference level (SNIR) is low then handover factor is higher medium
Rule-71	If RSSI is high and Data rate is medium and Velocity is high and Interference level (SNIR) is medium then handover factor is high
Rule-72	If RSSI is high and Data rate is medium and Velocity is high and Interference level (SNIR) is high then handover factor is high
Rule-73	If RSSI is high and Data rate is high and Velocity is low and Interference level (SNIR) is low then handover factor is lower medium

Rule-74	If RSSI is high and Data rate is high and Velocity is low and Interference level (SNIR) is medium then handover factor is higher medium
Rule-75	If RSSI is high and Data rate is high and Velocity is low and Interference level (SNIR) is high then handover factor is high
Rule-76	If RSSI is high and Data rate is high and Velocity is medium and Interference level (SNIR) is low then handover factor is higher medium
Rule-77	If RSSI is high and Data rate is high and Velocity is medium and Interference level (SNIR) is medium then handover factor is high
Rule-78	If RSSI is high and Data rate is high and Velocity is medium and Interference level (SNIR) is high then handover factor is high
Rule-79	If RSSI is high and Data rate is high and Velocity is high and Interference level (SNIR) is low then handover factor is high
Rule-80	If RSSI is high and Data high is low and Velocity is high and Interference level (SNIR) is medium then handover factor is high
Rule-81	If RSSI is high and Data rate is high and Velocity is high and Interference level (SNIR) is high then handover factor is higher

4.4 Data rate calculation

Here we adopt path loss channel propagation model for macrocell users can be expressed as [20-21]

$$L = 69.55 + 26.16\log_{10} f_{c,m} - 13.82\log_{10}(h_b) - a(h_m) + [44.9 - 6.55\log_{10} h_b]\log_{10} d + L_{sh}[\text{dB}] \quad (12)$$

$$a(h_m) = 1.1\lfloor \log_{10} f_{c,m} - 0.7 \rfloor h_m - (1.56\log_{10} f_{c,m} - 0.8) \quad (13)$$

where L is the path loss, $f_{c,m}$ is the center frequency in MHz of the macrocell, h_b is the height of the macrocellular BS in meter, h_m is the height of the MS in meter, d is the distance between the macrocellular BS and the MS in kilometer, L_{sh} is the shadowing standard deviation.

The propagation model for femtocell users can be expressed as [10]:

$$L_{femto} = 20\log_{10} f_{c,f} + N\log_{10} d_1 - 28[dB] \qquad (14)$$

where $f_{c,f}$ is the center frequency in MHz of the femtocell, d_1 is the distance between the FAP and the MS in meter

The expression of received signal strength indicator (RSSI) is

$$L = 10\log\frac{P_T}{P_R} \qquad (15)$$

$$P_R = P_T 10^{\frac{-L}{10}} \qquad (16)$$

where P_T is the transmitted power and P_R is the received power, and L is the path loss.

The received SNIR level of femtocell user in a macrocellular integrated network or femtocellular integrated network can be expressed as

$$SNIR = \frac{S_{f0}}{\sum_{i=0}^{N} I_{i,f} + \sum_{p=0}^{M} I_{i,m} + N_l} \qquad (17)$$

where S_{f0} is the power of the received signals from the associated macrocellular base station or FAP, $I_{i,f}$ is the power of the interference signal from the i-th interfering femtocell from among the N neighboring femtocell users and $I_{i,m}$is the received interference signal from the p-th macrocell from among the M macrocell users. N_l is the presented noise level.

The data rate of femtocell and macrocell users achieved are given below,

$$C_f = B_f \log_2(1 + SNIR_f) \qquad (18)$$

$$C_m = B_m \log_2(1 + SNIR_m) \qquad (19)$$

where B_f and B_m are, respectively, the allocated bandwidth for a user in femtocell and macrocell network and $SNIR_f$ and $SNIR_m$ are , respectively, SNIR level at targeted femtocell and macrocell networks.

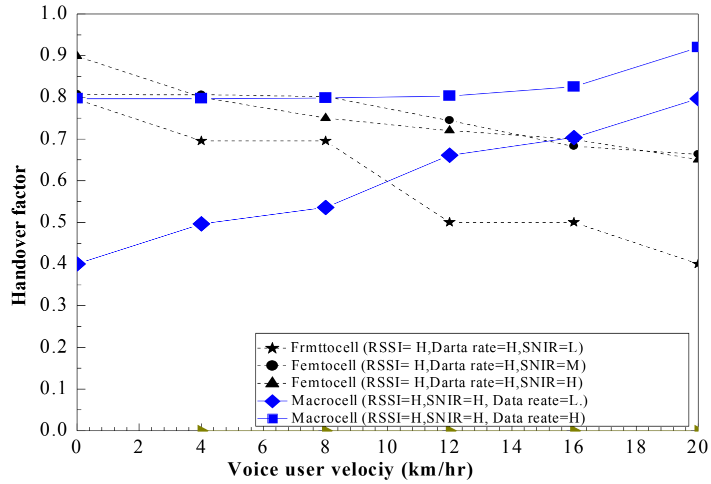
Chapter 5

Performance Analysis

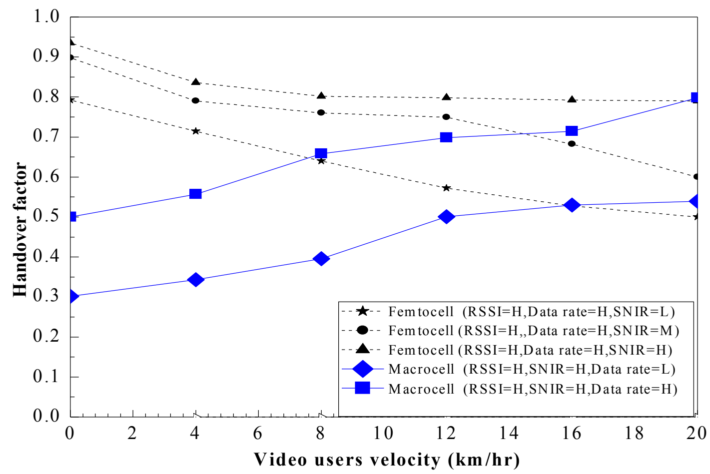
In this section, we analyze the performance of our proposed scheme. We considered voice and video services for the analysis. We can easily make decisions to switch between macrocell and femtocell. Figs. 5.1-5.3 show the calculated handover factors with respect to velocity of users considering both macrocell and femtocell as target networks. We considered different conditions of network parameters as RSSI, data rate, and SNIR. We assume K=1 for the analysis. The system calculates the handover factors and, then based on the calculated factors, the target network for handover is selected. Figs. 5.1-5.3 also show femtocell and macrocell networks handover factors for voice and video services.

5.1 Handover factor vs velocity at high inputs parameters

In Fig. 5.1, RSSI of macrocell user are at high condition. In femtocell network, user's RSSI and data rate are high condition but varied SNIR as low, medium, and high conditions. On the other hand, in macrocell network, user's SNIR are kept high but varied data rate as low, medium, and high conditions. In case of voice both (femto and macro) curves intersect at velocity 10km/hr and 16km/hr. Before these velocity points, the MS can choose femtocell. However, after these intersecting points, for case-1 scenario, the MS handover to femtocell or remains in macrocell network as RSSI and SNIR are high. For case-2 scenario, the MS choose for handover either macrocell or femtocell. Another case is video, at the same condition of input parameters at voice the MS choose femtocell network most. There are two intersecting points at velocity 8.5km/h and 16.5km/hr and after the intersecting points, for case-1 scenario, the MS remains in macrocell or choose femtocell network if necessary. However, for case-2 scenario, the MS choose handover to femtocell or macrocell networks which is more preferable for this service but handover factor is higher in femtocell for video so it is chosen at this situation. At the same conditions of network parameters, the value of handover factor for voice service differs from handover factor of video service. Handover factor of voice at femtocell is less but more in video. For user consideration, choice and availability of networks parameters some facts femtocell are preferable and for some facts are macrocell. For video, femtocell is more preferable than macrocell which is shown in fig. 5.1.



(a)

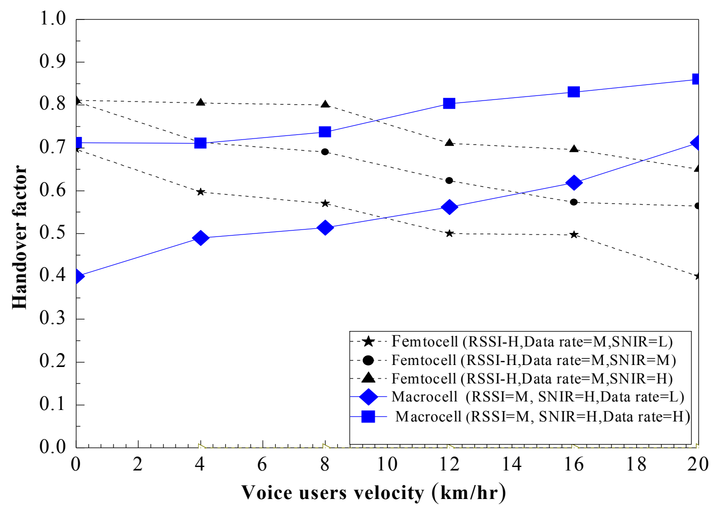


(b)

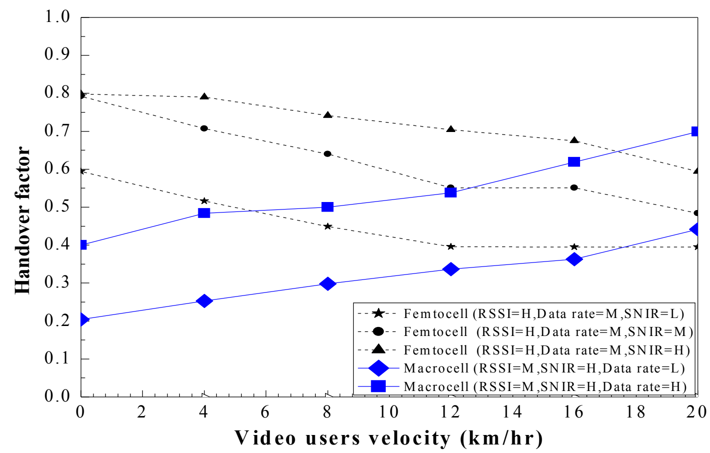
Fig. 5.1. Handover factor vs user velocity considering at high inputs parameters (a) voice service and (b) video service.

5.2 Handover factor vs velocity at medium inputs parameters

In Fig. 5.2 RSSI of microcell user's are at medium conditions. In femtocell network, user's RSSI are high conditions and data rate are medium condition. However, user's SNIR varied as low, medium, and high conditions. On the other hand, in macrocell network, user's SNIR are high but varied data rate as low, medium and high conditions as well. In case of voice both (femto and macro) curves intersect velocity at 4 km/hr and 10 km/hr, and 14 km/hr.



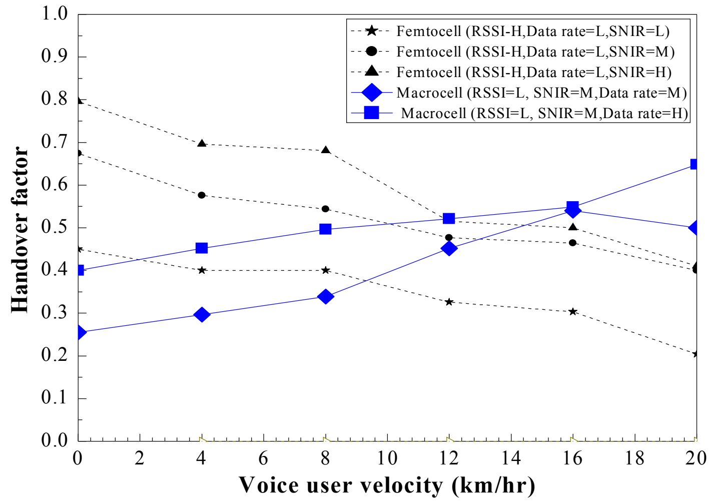
(a)



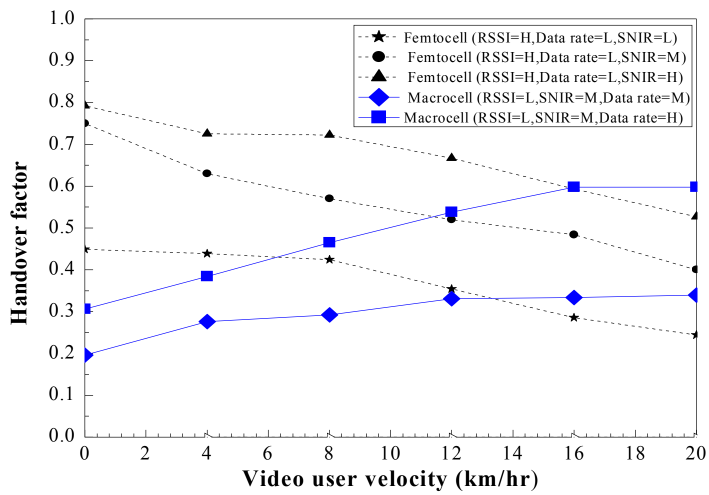
(b)

Fig. 5.2. Handover factor vs user velocity considering at medium inputs parameters (a) voice service and (b) video service.

Before these velocity points, the MS can choose femtocell. However, after passingintersecting points, for case-1 scenario, MS choose femotocell for handover or remain in macrocell as RSSI and SNIR are medium. for case-2 scenario, MS choose handover either macrocell or femtocell as the availability of networks parameters. Another case is video, but at the same conditions for video, velocity shift from 5km/hr, 13km/hr, and 18km/hr, respectively and MS choose femtocell network most that's why it's velocity is shifted and more time to stay in femtocell network. There are three intersecting points at velocity 5km/h and 13km/hr and 18km/hr after the intersecting points the MS choose macrocell if necessary



(a)



(b)

Fig. 5.3 Handover factor vs user velocity considering at low inputs parameters (a) voice service and (b) video service

but handover or stay to femtocell is much more preferable as handover factor is higher in femtocell for video. At the same conditions of network parameters, the value of handover factor for voice service differs from handover factor of video service. Handover factor of voice at femtocell is less but more in video. For user consideration, choice and availability of networks parameters some facts femtocell are preferable and for some facts are macrocell. Here in case of video, femtocell is more acceptable. However, more intersecting points gives

MS an opportunity to choose between macrocell and femtocell for handover considering user preference.

5.3 Handover factor vs velocity at low inputs parameters

In Fig. 5.3 RSSI of macrocell user's are at low condition. In femtocell network, user's RSSI are high condition and data rate are low condition but varied SNIR as low, medium, and high conditions. On the other hand, in macrocell network, user's SNIR are medium condition but varied data rate as low, medium and high conditions. In case of voice both (femto and macro) curves intersect velocity at 2km/hr and 9km/hr, and 12 km/hr and, 16 km/hr. Before these velocity points, the MS can choose femtocell or remain in macrocell network, for case-1 scenario. However, after passing intersecting points above velocity condition of handover, for case-2 scenario, MS can choose handover either macrocell or femtocell. Another case is video, but at the same conditions for video, velocity shift from 7km/hr, 12.5km/hr, and 16.5km/hr, respectively and MS choose femtocell network most that's why it's velocity is shifted and more time to stay in femtocell network. There are three intersecting points at velocity 7km/h and 12.5km/hr and 16km/hr after the intersecting points the MS choose macrocell if necessary but handover or stay to femtocell is much more preferable as handover factor is higher in femtocell for video. At the same conditions of network parameters, the value of handover factor for voice service differs from handover factor of video service. Handover factor of voice at femtocell is less but more in video. For user consideration, choice and availability of networks parameters some facts femtocell are preferable and for some facts are macrocell. Here in case of video, femtocell is more as well. From the overall analysis, we can conclude that video service prefers to handover femtocell more than macrocell

The designs are simulated using fuzzy logic tool on MATLAB platform. In our scheme, we consider three services which are badly needed in mobile communication. In case of video and data services, we can prefer femtocell more than macrocell. So by considering the perspective of services of users, the proposed model will surely help the distribution of valuable spectrum.

Chapter 6

Conclusion

There is an increase in the percentage usage of many high data rate applications over the past few years and this trend will most certainly persist on in the future. Due to the high demand, our wireless technologies such as WiMAX, WiFi, WLAN, femtocell, macroccell etc. have been researched upon to improve user types and prerequisite. Our work mainly designs a handover decision mechanism. This handover design mechanism is considered for macrocell/femtocell integrated network. We consider macrocell to femtocell, femtocell to macrocell and femtocell to femtocell all three possible handover scenarios. Different service requires different QoS level. If the system uses same handover process for all cases of services then efficient and perfect handover may not be executed. For this concern, we consider service priority handover call. For this reason, we initially consider service type and its QoS requirement. Then we consider diverse service type for handover decision mechanism. Therefore, we calculate handover factor and based on the handover factor the handover decision is executed. The research proposes service aware fuzzy rule-based intelligent handover decision where network parameters are RSSI, data rate, velocity and interference level (SNIR) for femtocell and macrocell networks. We analyze the performance of network parameters considering service type such as voice, video, and data. By investigating performance parameter of velocity vs handover factor for, we notice that by the decreasing of input parameter the intersecting points are increasing because the value of network parameter are low which affect the macrocell and femtocell networks. For voice and video services at same condition of input parameters different performance are shown. We have shown voice and video services here and more services like data, video streaming, conference call, multimedia message can be shown in the same manner further. Our proposed scheme shows that femtocell is preferable for video service as it requires high data rate and low cost. Voice prefers macrocell as it needs high RSSI, high mobility and less delay. If a situation is created that handover factor of femtocell is greater than handover factor of macrocell or the performance curve of macrocell is crossed higher than femtocell then MS chooses femtocell for handover as it is low cost and support high data rate and less traffic load. The analysis also indicates the different effects of macrocell and femtocell networks for different conditions of network parameters. However, our proposed scheme provides a good basis for research of handover decision using fuzzy logic based on user services successfully.

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