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Mutual Authentication Technique with Four Entities Implemented by Fuzzy Neural Network in 4-G Mobile Communications

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ABSTRACT

4-G mobile communications system is offering high speed data communications technology having connectivity to all sorts of the networks including 2-G and 3-G mobile networks. Authentication of a mobile subscriber (MS) or a sub network and a main network are an important issue to check and minimize security threats or attacks. An advanced artificial intelligence based mutual authentication technique executed by fuzzy neural network with four entities is proposed. Voice frequency of the salutation or the selective words used by a subscriber like Hello, Good Morning, etc. is taken as first entity. Second entity is chosen as thumb fingerprint matching of the calling subscriber with his / her stored thumb fingerprint. Then third entity is taken as face image matching of the calling subscriber. Fourth entity is granted as probability of the salutation word from subscriber's talking habit while initializing a call. These four entities such as probability of particular range of frequencies for the salutation word, the thumb fingerprint matching, the face image matching of the subscriber, using particular salutation or greeting word at the time of starting a call are used with most frequently, more frequently and less frequently by the calling subscriber like uncertainty in Artificial Intelligence. Now different relative grades are assigned to most frequently, more frequently and less frequently used parameters. Fuzzy operations such as intersection and union are computed taking three membership functions at a time out of four membership functions to adopt fuzzy neural network. Thereafter, the optimum or the final fuzzy operations are computed according to the assumed weightages. Lastly, the optimized fuzzy operations are defuzzified by the Composite Maxima method, and the results are tested according to the invented fuzzy neural rule. If the results are satisfactory, the subscriber or the sub network and the network (the switch or the server) are mutually authenticated in 4-G mobile communications.

Keywords: Biometric scheme, Face image matching, Fuzzy neural network, Fuzzy operation, Identifier, Mutual authentication, Salutation word, Thumb fingerprint matching.

I. INTRODUCTION

Fourth generation (4-G) mobile communications system is offering high speed data communications technology having connectivity to all sorts of networks including 2-G and 3-G mobile networks [1]-[9]. Authentication of a mobile subscriber or a sub network with a main network in 4-G mobile communications is an important criterion to check and minimize security threats and attacks [6]-[9], [17]-[21]. An advanced artificial intelligence (AI) based mutual authentication technique applying fuzzy neural network algorithm with four entities is proposed in this paper. Generally the scientists may not be able to provide error free data or knowledge using fuzzy logic system [12]-[16]. For that a neuro fuzzy system can be used to tune the system and reject unnecessary or redundant fuzzy rules. A neuro fuzzy system has multi-layers that embed the fuzzy system [12]-[16].

A person talking salutation or greeting words in different times are always consisting of a very narrow range of frequencies (0.2 ~ 3.5 KHz) which are varying in nature from person to person. Thus voice frequency of the salutation or the selective words used by a subscriber like Hello, Good Morning etc. is taken as first entity. Second entity is chosen as matching the thumb fingerprint of the calling subscriber with his / her stored thumb fingerprint in the database of the network. Then third entity is taken as the coloured face image matching of the calling subscriber with his / her stored coloured face image at the network (the switch or the server). Fourth entity is granted as probability of the salutation or the greeting word from the subscriber's talking habit (set of salutation words) while initializing a call.

These four entities such as the probability of particular range of frequencies for the salutation word, the thumb fingerprint matching, the coloured face image matching of the subscriber, the particular salutation or the greeting word at the time of starting a call are used with most frequently, more frequently and less frequently by the calling subscriber like uncertainty in Artificial Intelligence (AI).

Now different relative grades are assigned for most frequently, more frequently and less frequently used parameters. This fuzzy membership function values for the entity or the parameter are assigned according to satisfy the change in values or importance of the entity with practical results. Fuzzy membership operations like fuzzy set intersection or minimum and union or maximum are computed taking three membership functions at a time out of four membership functions to adopt fuzzy neural network [12]-[16].

Thereafter, the optimum fuzzy operations are computed according to the assumed weightages. These weightages are assigned for controlling the fuzzy neural rule (condition) and the best suited values are considered in accordance with the specific value of the entities causing authentication fail while testing the fuzzy neural rule.

Then these optimized fuzzy operations are defuzzified by the Composite Maxima method, and tested according to the invented fuzzy neural rule.

If the results obtained from the fuzzy neural network are satisfactory, the subscriber (MS) or the sub network and the network (the switch or the server) are mutually authenticated in 4-G mobile communications.

II. ARCHITECTURE OF 4-G MOBILE SYSTEM

Architecture of a fourth generation (4-G) wireless network [10]-[11], [17]-[21] is described below in Fig. 1. This 4-G network can provide circuit switched voice service, circuit switched data service like 2-G (CDMA One or GSM), 3-G (WCDMA, CDMA-2000, UMTS) [1]-[9] in addition to this packet switched data and multimedia service at a very high data rate. Mobile Subscriber (MS), Base Transceiver Station (BTS), Base Switching Center (BSC), Main Switching Center (MSC), Public Switched Telephone Network (PSTN), Public Data Network (PDN), Integrated Services Digital Network (ISDN), Internet Protocol (IP) Network, Authentication, Authorization and Accounting (AAA) Server, other Servers, Workstations, Gateways, etc. are functioning same way as it is in 2-G or 3-G mobile communications networks.

Radio Network Controller (RNC) in Universal Mobile Telecommunication System (UMTS) is belonging to 3-G and 4-G like BSC in GSM or CDMA in 2-G and 3-G. In UMTS system 3-G and 4-G, the core network, i.e., the server or the switch consists of Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN) which are interconnected via IP network.

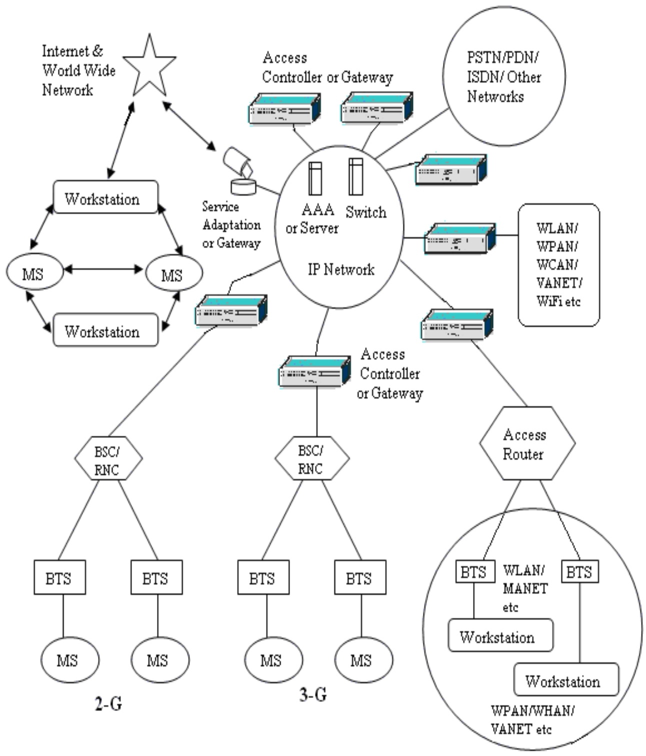

Figure 1: Network architecture of 4th Generation (4-G) mobile communications system

The SGSN keeps track the location of an individual mobile station, performs security functions and access control. The GGSN encapsulates packets received from external IP networks and routes them towards the SGSN. GGSN directs outside data to SGSN [5]-[11], [17]-[21]. SGSN is connected to the Radio Network Controller (RNC) or BSC which is further attached to BTS via asynchronous transfer mode; both RNC and BTS stay in UMTS Terrestrial Radio Access Network (UTRAN) unit. RNC is in charge of the overall control of the logical resources provided by UTRAN.

III. METHODS AND MATERIAL

Data rate dimensioning targets for 4-G is 50 to 500 bit/s/Hz/Km^2, i.e., 100 Mbps ~ 2 Gbps, whereas in 3-G it is around 10 bit/s/Hz/Km^2, i.e., up to 2 Mbps using High Speed Uplink Packet Access (HSUPA) and High Speed Downlink Packet Access (HSDPA) technology. MSC controls all the functions of a mobile network via different registers, especially for voice and low speed data communications, and Server controls all the functions via different registers for voice and high speed data communications through packet switching technology.

Access Controller or Gateway provides connection to user's network (MS or sub network) with the server or the switch. In essence, 4-G aims to transfer communications architectures from traditional vertical stovepipe to horizontal integrated systems. Personal Networks like WLAN, WPAN, WCAN, WHAN, ISDN, PSTN, PDN, MANET, VANET, Wi-Fi, WiMAX, LTE etc. are a dynamic network building on the above mentioned wireless networking technologies, which facilitate personalized communications with any number of subscribers anywhere at any time. Latest mobile technologies such as Worldwide Interoperability of Microwave Access (WiMAX) is standardized in 2008 A.D., offering data rate up to 40 Mbps, and Long Term Evolution (LTE) is standardized in 2010 A.D., extending data speed up to 100 Mbps using Orthogonal Frequency Division Multiplexing (OFDM) or Orthogonal Frequency Division Multiple Access (OFDMA) technique with Multiple-Input-Multiple-Output (MIMO) antennas. Thus, WiMAX and LTE are highly recommended for 4-G mobile communications. Then the personal networks can be expanded or shrunken depending on the availability of users, their demands and environment. 4-G mobile network works seamlessly on the basis of Internet protocol IPv4 or IPv6. All sub networks are connected through the gateways and the access controllers to afford worldwide connectivity.

Mutual Authentication Technique Methodology Executed by Fuzzy Neural Network in 4-G Mobile Communications

The proposed technique has two phases, namely, Subscriber Enrolment Phase and Subscriber Authentication Phase. Subscriber Enrolment Phase is done at the time of enrolment of a subscriber in a network and any modification of information or data, when it is requested by the subscriber (the MS or the sub network).

(i) Subscriber Enrolment Phase

The subscriber is enrolled to a particular switch or a server belonging to the network. In case of a sub or small network like WLAN, WPAN, MANET, etc. connected with the 4-G mobile network via an access controller or a gateway, the Controller or the Manager of the sub network feeds the required entities or parameters and acts as a subscriber (MS). This phase is executed once.

ASE1: The subscriber sends an application request to the mobile service provider for a new SIM.

ASE2: After receiving the request, the authority asks to submit his / her different parameters of talking and the thumb's fingerprint and the coloured face image (biometric attributes) for storing in the database of the network against his / her mobile phone number.

ASE3: (i) Which frequency range in voices is appearing most frequently, more frequently and less frequently used by the subscriber in talking the salutation words?
(ii) How much the calling subscriber's thumb fingerprint is matched most frequently, more frequently and less frequently with his / her stored thumb fingerprint in the network?
(iii) How much the calling subscriber's coloured face image is tallied most frequently, more frequently and less frequently with his / her stored coloured face image in the network?
(iv) Which salutation words are most frequently, more frequently and less frequently used by the calling subscriber at the time of starting a mobile call?

The frequency of the salutation word is measured by a sophisticated electronics instrument in Hz, better up to one decimal place. The thumb fingerprint and the coloured face image of a calling subscriber are taken by a digital camera with high resolution; generally both the instruments may be inbuilt in a mobile phone (MS). A vertical indicator line is drawn on top of the camera in the MS, the tip of the thumb for fingerprint, and the tip of the nose of the calling subscriber for face image are to be placed just above the indicator line, so that, the images supplied by the subscriber in different times are similar type or less distorted.

ASE4: The authority uses above four databases in the server or the switch for storing the subscriber's parameters based on the talking habit. The first database, D_V stores the subscriber most frequently, more frequently and less frequently used voice frequencies for each salutation word and its corresponding relative grades. The first range of voice frequency for the salutation word most frequently used, D_{VR1} of D_V, is assigned relative grade or weightage by 0.65. The second class D_{VR2} of D_V, stores more frequently used voice frequency of the salutation word having relative grade 0.55. The third range D_{VR3} of D_V, is less frequently used frequency of the salutation word with relative grade 0.25.

Likewise a database is prepared for measuring the frequency range of the salutation word most frequently, more frequently and less frequently for predicted all the salutation words used by the subscriber. D_{VR1}, D_{VR2}, D_{VR3} of D_V is calculated as per following formula. Suppose, D_V ranges between 'a' Hz (lower frequency) to 'b' Hz (higher frequency), the server or the switch computes this, $c = (a + b)/2$ and $d = (b - a)/6$ [since three equal divisions are made]. D_{VR1} ranges between $e = (c - d)$ Hz to $f = (c + d)$ Hz. D_{VR2} ranges between $g = (e - d)$ Hz to $h = (e - 1)$ Hz or $i = (f + 1)$ Hz to $j = (f + d)$ Hz. D_{VR3} ranges between $k = (g - d)$ Hz = a Hz to $l = (g - 1)$ Hz or $m = (j + 1)$ Hz to $n = (j + d)$ Hz = b Hz.

The second database, D_F stores the thumb fingerprint images of all subscribers against their mobile numbers in the server or the switch of a network, e.g., each thumb fingerprint image consists of a square matrix having (128 × 128) pixels, but any pixel-size of the thumb fingerprint may be taken. The thumb fingerprint images are monochromatic, i.e., black and white coloured. Then the calling subscriber's thumb fingerprint image is compared with his / her stored thumb fingerprint image in the database (noted against his / her mobile number) by matching each location pixel, i.e., pixel-wise comparing. The numbers of pixels are matched either having the same values of the pixels containing in the thumb fingerprint image (completely matched) or making threshold to some limiting values, i.e., the mismatched pixels' values are considered up to certain range or any appropriate value. If the calling subscriber's thumb fingerprint matching to his / her stored thumb fingerprint image falls under category of more than 80% to 100% pixels matching, relative grade is 0.8, stored in D_{FR1}. If within 60% to 80% pixels are matched for the calling subscriber's thumb fingerprint image, relative grade is 0.6, stored in D_{FR2}. If less than 60% pixels are matched, relative grade is 0.3, stored in D_{FR3}.

The third database, D_I stores the coloured face images of all subscribers against their mobile numbers in the server or the switch of a network. Each coloured face image contains square size (128 × 128) pixels, but any pixel-size may be considered. First coloured face images are separated in three primary colours like R (Red), G (Green), B (Blue) parts. Then the calling subscriber's coloured face image is compared with his / her stored coloured face image in the database by matching each location pixel, i.e., pixel-wise comparing separately for the R, G, B parts. The numbers of pixels are matched either having the same values of the pixels containing in the face image, i.e., completely matched or taking threshold to some limiting values, i.e., the mismatched pixels' values are considered up to certain range or any appropriate value. Lastly, the average value of the matching pixels in the R, G, B parts is computed. Also RGB coloured images may be converted to HSV or any other attributes, and the face image matching can be executed for those attributes. If the calling subscriber's coloured face image matching to his / her stored coloured face image (in the network) falls under category of more than 80% to 100% pixels matching, relative grade is 0.9 and it is stored in D_{IR1}. If within 60% to 80% pixels are matched for the calling subscriber's coloured face image, relative grade is 0.7 and stored in D_{IR2}. If less than 60% pixels are matched, relative grade is 0.3, and it is stored in D_{IR3}.

The fourth database, D_W stores most frequently, more frequently and less frequently used salutation words and their corresponding relative grades. The first row, D_{WR1} of D_W, stores most frequently used salutation words with relative grade 0.9. The second row, D_{WR2} of $D_{W,}$ is identified more frequently used salutation words with relative grade 0.6. The third row, D_{WR3} of D_W, belongs to less frequently used salutation words with relative grade 0.3.

Subscriber's flipping frequency may be considered as second entity in place of thumb fingerprint matching.

ASE5: If the authority does not get sufficient information, request for resubmission the correct signature or the database of the subscriber is placed. Then the authority executes the above steps again for strong database.

(ii) Subscriber Authentication Phase

When a subscriber initiates a call by speaking a salutation word, then the authentication process starts. In this time the server or the switch, i.e., the network executes the following operations:

ASA1: The server or the switch finds the matched frequency of the salutation word within the rows $D_{VR1,}$ D_{VR2}, D_{VR3} of D_V.

ASA1.1: After hearing the first word from a subscriber, either the MS or the network computes the frequency of the salutation word, then match the voice frequency of the salutation word within the stored range $D_{VR1,}$ D_{VR2}, D_{VR3} of D_V and its corresponding relative grade which is taken as v1, If not match, v1 = 0.

The membership functions of a fuzzy set F1 is defined as follows, $\mu_{F1}(a1) = v1$, hence, F1 = {(a1, v1)}.

ASA2: Finds the matched thumb fingerprint percentage by matching pixels within the rows $D_{FR1,}$ D_{FR2}, D_{FR3} of D_F.

ASA2.1: If the thumb fingerprint of the MS (Calling Party) is matched, then it stores, p1= Relative grade of matched location in the row; otherwise, p1=0. The membership functions of a fuzzy set F2 is $\mu_{F2}(a2) = p1$, hence, F2 = {(a2, p1)}.

ASA3: The server or the switch finds the matched subscriber's face image percentage by comparing pixels within the rows $D_{IR1,}$ D_{IR2}, D_{IR3} of D_I.

ASA3.1: If the coloured face image of the MS (Calling Subscriber) is matched with the stored coloured face image pixel-wise, then it stores value, q1= Relative grade of matched location in the row; otherwise, q1=0. The membership functions of a fuzzy set F3 is, $\mu_{F3}(a3) = q1$, hence, F3 = {(a3, q1)}.

ASA4: Finds the matched salutation or the greeting word within the rows $D_{WR1,}$ D_{WR2}, D_{WR3} of D_W.

ASA4.1: If the salutation word is matched within the stores value of $D_{WR1,}$ D_{WR2}, D_{WR3}, then it stores value, w1= Relative grade of the matched salutation word in the row; otherwise, w1=0. The membership functions of a fuzzy set F4 can be, $\mu_{F4}(a4) = w1$, hence, F4 = {(a4, w1)}.

ASA5: The server or the switch computes the fuzzy operations such as fuzzy set intersection (minimum) and union (maximum) taking three fuzzy membership functions at a time out of total four fuzzy membership functions; the four different values of each fuzzy operation such as fuzzy set intersection or union are obtained as mentioned below.

ASA5.1:

$T_1 = \mu_{F1\cap F2\cap F3}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\}$,

$T_2 = \mu_{F1\cap F2\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\}$,

$T_3 = \mu_{F2\cap F3\cap F4}(a) = \min\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\}$,

$T_4 = \mu_{F1\cap F3\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\}$.

ASA5.2:

$V_1 = \mu_{F1UF2UF3}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\}$,

$V_2 = \mu_{F1UF2UF4}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\}$,

$V_3 = \mu_{F2UF3UF4}(a) = \max\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\}$,

$V_4 = \mu_{F1UF3UF4}(a) = \max\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\}$.

ASA6: For ascertaining authenticity of the mobile subscriber (MS) as well as the network (MSC or Server), fuzzy neural network algorithm on the results of the fuzzy operations have been applied.

Different weightages to these fuzzy operations (intersection and union) are imposed, and these weightages are assigned by altering different values in practical examples in accordance with any one or two entities, from voice frequency matching, face image matching, fingerprint matching, probability of salutation words, belonging to the least relative grade or the lowest fuzzy membership function value causing authentication fail while examining the fuzzy neural rule.

$WT_1 : WT_2 : WT_3 : WT_4 = 0.5 : 0.4 : 0.35 : 0.3$,

$WV_1 : WV_2 : WV_3 : WV_4 = 0.9 : 0.8 : 0.7 : 0.65$.

The values of the fuzzy operations are multiplied by the corresponding weightages for computing the optimum or the final values, i.e.,

$FT_1 : FT_2 : FT_3 : FT_4 = T_1 \times WT_1 : T_2 \times WT_2 : T_3 \times WT_3 : T_4 \times WT_4 = 0.5T_1 : 0.4T_2 : 0.35T_3 : 0.3T_4$,

$FV_1 : FV_2 : FV_3 : FV_4 = V_1 \times WV_1 : V_2 \times WV_2 : V_3 \times WV_3 : V_4 \times WV_4 = 0.9V_1 : 0.8V_2 : 0.7V_3 : 0.65V_4$.

The block diagram of the mutual authentication technique applying fuzzy neural network is delineated below in Fig. 2.

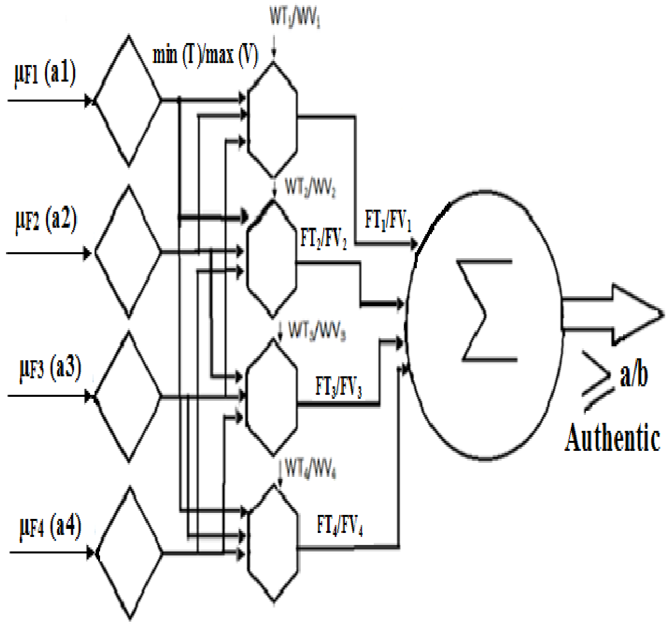

Figure 2: Block diagram of the mutual authentication technique implemented by fuzzy neural network in 4-G Mobile Communications

ASA7: All the final values of a particular fuzzy operation are defuzzified by a defuzzifying function by the server or the switch. Defuzzification is done by the Composite Maxima method, i.e., $\max(FT_1, FT_2, FT_3, FT_4) = a$, and $\max(FV_1, FV_2, FV_3, FV_4) = b$.

ASA8: The fuzzy neural rule on the results of the final defuzzified outputs are determined according to examine different values on the practical examples, and then the best suited values are taken.

Thus as per fuzzy neural rule, if $a \geq 0.24$ and $b \geq 0.63$ both satisfies, then only the network (the switch or the server) ensures that the subscriber (MS) or the sub network is authentic; hence, their mutual authenticity is verified. Also if the above two fuzzy neural conditions or any one of them are not satisfied, the network ensures that the user (the subscriber or the sub network) is unauthentic. In this case the network, i.e., the switch or the server sends an authentication failure message to the subscriber or the sub network.

IV. RESULTS AND DISCUSSION

Example 1: A subscriber starts talking with "Hello" in 2536 Hz, the thumb fingerprint is matched 69.848% to his stored thumb fingerprint, and the coloured face image of the subscriber is matching with his stored coloured face image by 76.367% pixels, examine mutual authenticity of the subscriber with the network.

After testing voice frequency of the subscriber's particular salutation word "Hello" stored in the server, the range of voice frequency for "Hello" is found from 2125 Hz to 2893 Hz. Then it is divided into relative grades.

TABLE I. VOICE FREQUENCY vs. RELATIVE GRADES OF D_V

Voice Frequency of the Salutation Word	Grade of D_V
2381 Hz to 2637 Hz	$D_{VR1} = 0.65$
2253 Hz to 2380 Hz; 2638 Hz to 2765 Hz	$D_{VR2} = 0.55$
2125 Hz to 2252 Hz; 2766 Hz to 2893 Hz	$D_{VR3} = 0.25$

TABLE II. THUMB FINGERPRINT MATCHED PERCENTAGE vs. RELATIVE GRADES OF D_F

Thumb Fingerprint Matched Percentage	Grade of D_F
Greater than (>) 80% to 100%	$D_{FR1} = 0.8$
60% to 80%	$D_{FR2} = 0.6$
Less than (<) 60%	$D_{FR3} = 0.3$

TABLE III. FACE IMAGE MATCHED PERCENTAGE vs. RELATIVE GARDES OF D_I

Face Image Matched Percentage	Grade of D_I
Greater than (>) 80% to 100%	$D_{IR1} = 0.9$
60% to 80%	$D_{IR2} = 0.7$
Less than (<) 60%	$D_{IR3} = 0.3$

TABLE IV. SALUTATION WORD vs. RELATIVE GRADES OF D_W

Salutation or Greeting Words	Grade of D_W
Hello, Oh God, Hi Guru, Jai Ram, Adab, Namaste.	$D_{WR1} = 0.9$
Good Morning, Good Afternoon, RadheRadhe, Achhaya, KaisaHai.	$D_{WR2} = 0.6$
Namaskar, AssalamoAlaokum, Joyguru, Hare Ram, Hare Krishna.	$D_{WR3} = 0.3$

For salutation word "Hello" is in D_{WR1}, grade w1 is 0.9 Hence, the matched frequency of the salutation word (2536 Hz) from the subscriber is in D_{VR1} of D_V whose relative grade is 0.65.

Therefore, v1= 0.65, $\mu_{F1}(a1) = v1 = 0.65$.

Hence, F1 = {(a1, 0.65)}.

The matched thumb fingerprint (69.848%) of the subscriber belongs to D_{FR2} of D_F having relative grade 0.6

Therefore, p1 = 0.6, $\mu_{F2}(a2) = p1 = 0.6$.

Hence, F2 = {(a2, 0.6)}.

The matched coloured face image (76.367%) of the subscriber belongs to D_{IR2}.

Therefore, q1 = 0.7, $\mu_{F3}(a3) = q1 = 0.7$.

Hence, F3 = {(a3, 0.7)}.

The matched the salutation word "Hello" of the subscriber belongs to $D_{WR1.}$

Therefore, w1= 0.9, $\mu_{F4}(a4) = w1 = 0.9$.

Hence, F4 = {(a4, 0.9)}.

Now the fuzzy operations such as fuzzy set intersection (minimum) are computed taking three fuzzy membership functions out of total four fuzzy membership functions.

$T_1 = \mu_{F1\cap F2\cap F3}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \min\{0.65, 0.6, 0.7\} = 0.6$,

$T_2 = \mu_{F1\cap F2\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \min\{0.65, 0.6, 0.9\} = 0.6$,

$T_3 = \mu_{F2\cap F3\cap F4}(a) = \min\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.6, 0.7, 0.9\} = 0.6$,

$T_4 = \mu_{F1\cap F3\cap F4}(a) = \min\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \min\{0.65, 0.7, 0.9\} = 0.65$.

Thereafter, we are applying fuzzy neural network algorithm to these fuzzy operations and accordingly the weightages of these fuzzy intersection operations are taken as,

$WT_1 : WT_2 : WT_3 : WT_4 = 0.5 : 0.4 : 0.35 : 0.3$.

Now the optimum or the final value is obtained multiplying the fuzzy intersection operation by the corresponding weightage, i.e.,

$FT_1 = T_1 \times WT_1 = 0.5T_1 = 0.5 \times 0.6 = 0.30$,

$FT_2 = T_2 \times WT_2 = 0.4T_2 = 0.4 \times 0.6 = 0.24$,

$FT_3 = T_3 \times WT_3 = 0.35T_3 = 0.35 \times 0.6 = 0.21$,

$FT_4 = T_4 \times WT_4 = 0.3T_4 = 0.3 \times 0.65 = 0.195$.

Then, all the final values regarding fuzzy intersection operations are defuzzified by the Composite Maxima method in fuzzy neural network, i.e., $\max(FT_1, FT_2, FT_3, FT_4) = \max(0.30, 0.24, 0.21, 0.195) = 0.30$.

Now the fuzzy operations like fuzzy set union (maximum) are calculated taking three fuzzy membership functions at a time out of four fuzzy membership functions.

$V_1 = \mu_{F1\cup F2\cup F3}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F3}(a3)\} = \max\{0.65, 0.6, 0.7\} = 0.7$,

$V_2 = \mu_{F1\cup F2\cup F4}(a) = \max\{\mu_{F1}(a1), \mu_{F2}(a2), \mu_{F4}(a4)\} = \max\{0.65, 0.6, 0.9\} = 0.9$,

$V_3 = \mu_{F2\cup F3\cup F4}(a) = \max\{\mu_{F2}(a2), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.6, 0.7, 0.9\} = 0.9$,

$V_4 = \mu_{F1\cup F3\cup F4}(a) = \max\{\mu_{F1}(a1), \mu_{F3}(a3), \mu_{F4}(a4)\} = \max\{0.65, 0.7, 0.9\} = 0.9$.

Weightages of this fuzzy union operations are as,

$WV_1 : WV_2 : WV_3 : WV_4 = 0.9 : 0.8 : 0.7 : 0.65$

The optimum or the final values regarding fuzzy union operation are mentioned below.

$FV_1 = V_1 \times WV_1 = 0.9V_1 = 0.9 \times 0.7 = 0.63$,

$FV_2 = V_2 \times WV_2 = 0.8V_2 = 0.8 \times 0.9 = 0.72$,

$FV_3 = V_3 \times WV_3 = 0.7V_3 = 0.7 \times 0.9 = 0.63$,

$FV4 = V_4 \times WV_4 = 0.65V_4 = 0.65 \times 0.9 = 0.585$.

All the final values are defuzzified by the Composite Maxima method which yields, i.e.,

$\max(FV_1, FV_2, FV_3, FV_4) = \max(0.63, 0.72, 0.63, 0.585) = 0.72$.

Now applying fuzzy neural rule, $\max(FT_1, FT_2, FT_3, FT_4) = 0.30$, i.e., ≥ 0.24, and $\max(FV_1, FV_2, FV_3, FV_4) = 0.72$, i.e., ≥ 0.63, therefore the network (the switch or the server) ensures that the subscriber or the sub network is authentic; hence, they are mutually authenticated.

This example is experimented in Matlab program 7.14 Version, and the process is described below. First of all the subscriber's database is stored in the server or the switch in Microsoft XL file and image file against his / her mobile number.

The coloured face image and the thumb fingerprint are stored in the database, and transmitted at the time of making a mobile call as noted below.

Stored in Database Transmitted at the time of calling

Face Image Name: pkb6.jpg pkb41.jpg

Thumb Fingerprint: tfp5.bmp tfp82.bmp

TABLE V. DATABASE FILE in MICROSOFT XL:

Sl. No.	Name of Salutation	Grade of Salutation	Voice Freq Low (V1)	Voice Freq High (V2)	Face Image Name	Finger-print Name
1	Hello	0.9	2125	2893	pkb6.jpg	tfp5.bmp
2	Oh God	0.9	1936	2578	pkb6.jpg	tfp5.bmp
3	Hi Guru	0.9	2145	2823	pkb6.jpg	tfp5.bmp
4	Jai Ram	0.9	1978	2567	pkb6.jpg	tfp5.bmp
5	Adab	0.9	1574	2168	pkb6.jpg	tfp5.bmp
6	Namaste	0.9	1975	2548	pkb6.jpg	tfp5.bmp
7	Good Morning	0.6	1520	2450	pkb6.jpg	tfp5.bmp
8	Good Afternoon	0.6	1954	2578	pkb6.jpg	tfp5.bmp
9	RadheRadhe	0.6	1479	2659	pkb6.jpg	tfp5.bmp
10	Achhaya	0.6	1748	2748	pkb6.jpg	tfp5.bmp
11	KaisaHai	0.6	1853	2364	pkb6.jpg	tfp5.bmp
12	Namaskar	0.3	1890	2654	pkb6.jpg	tfp5.bmp
13	AssalamoAlaokum	0.3	1943	2782	pkb6.jpg	tfp5.bmp
14	Joyguru	0.3	1754	2278	pkb6.jpg	tfp5.bmp
15	Hare Ram	0.3	1877	2486	pkb6.jpg	tfp5.bmp
16	Hare Krishna	0.3	1986	2537	pkb6.jpg	tfp5.bmp

(i) First Procedure: In this Matlab program, the results of the fingerprint matching and the coloured face image matching as given in the example are fed to the program directly, the results are noted below.

```
>> Example1
Enter Salutation Word: 'Hello'
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 2125.00
High Voice Frequency in Hz = 2893.00
Give Voice Frequency of Salutation Word in Hz: 2536
Membership Voice Frequency = 0.6500
Give Percentage Matching of Thumb Fingerprint: 69.848
Membership Thumb Fingerprint Matching = 0.6000
Give Percentage Matching of Face Image: 76.367
Membership Face Image Matching = 0.7000
The subscriber and the network are mutually authenticated.
Elapsed time is 9.217733 seconds.
>>
```

(ii) Second Procedure: In this Matlab program, the matching of the thumb fingerprint images and the coloured face images program are included in the main program, only the thumb fingerprint and the coloured face image (here the thumb fingerprint file name tfp82.bmp and the coloured face image file name pkb41.jpg) at the instant of calling are transmitted. Thumb fingerprint images are matching the gray values taking threshold value up to 5 for completely matching, because up to 5 differences in pixel values are not dominant in change of image or colour. The coloured face images are matched R, G, B attributes separately pixel-wise making threshold value up to 5 for complete matching, and the average pixel value of the R, G, B matching is computed. The following results are obtained.

```
>> Example1_ImageMatch
Enter Salutation Word: 'Hello'
Membership Salutation Word = 0.9000
Low Voice Frequency in Hz = 2125.00
High Voice Frequency in Hz = 2893.00
Give Voice Frequency of Salutation Word in Hz: 2536
Membership Voice Frequency = 0.6500
Give Thumb Fingerprint Image Name: 'tfp82.bmp'
Percentage Thumb Fingerprint Image Matching = 69.8486
Membership Thumb Fingerprint Matching = 0.6000
Give Face Image Name: 'pkb41.jpg'
Percentage Face Image Matching = 76.3672
Membership Face Image Matching = 0.7000
The subscriber and the network are mutually authenticated.
Elapsed time is 14.831422 seconds.
>>
```

V. ADVANTAGES OF THE PROPOSED AUTHENTICATION TECHNIQUE

Presently used authentication techniques in 2-G and 3-G mobile communications are based on cryptography algorithm using EX-OR operation, Bhattacharjee *et al.* deliberates a simple and fast authentication technique in this area by using hash function with EX-OR operation, but using artificial intelligence in mobile authentication techniques is firstly implemented by Bhattacharjee *et al.* [6]-[9], [18]-[19].

This authentication technique is the most efficient due to applying artificial intelligence [AI] in advanced stage, i.e., fuzzy neural network applied [20]-[21]. Also it does not require any further information to be supplied by the subscriber (MS) while making a call. So it is a unique one. Authenticity is determined by the subscriber's talking characteristics (habits), the biometric parameters like the thumb fingerprint, and the coloured face image analysis. No cryptography algorithm or any complex functions are applied. This authentication technique ensures correct results within real time basis.

VI. CONCLUSION

In this proposed fuzzy neural network based mutual authentication technique, the subscriber or the sub network as well as the main network mutual authentication scheme is developed in fourth generation (4-G) mobile communications. A novel artificial intelligence system in the form of fuzzy neural network is introduced to the network (the server or the switch) for higher accuracy and stable mutual authentication system. The results obtained by this technique are highly suitable to practical environment. Therefore, this technique affords mutual authentication in 4-G mobile communications within a real time basis.

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