KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS VOL. 10, NO. 11, Nov. 2016 5229

A Multi-Attribute Intuitionistic Fuzzy Group Decision Method For Network Selection In Heterogeneous Wireless Networks Using TOPSIS

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Received May 9, 2016; revised October 16, 2016; accepted October 18, 2016; published November 30, 2016

Abstract

With proliferation of diverse network access technologies, users demands are also increasing and service providers are offering a Quality of Service (QoS) to satisfy their customers. In roaming, a mobile node (MN) traverses number of available networks in the heterogeneous wireless networks environment and a single operator is not capable to fulfill the demands of user. It is crucial task for MN for selecting a best network from the list of networks at any time anywhere. A MN undergoes a network selection situation frequently when it is becoming away from the home network. Multiple Attribute Group Decision (MAGD) method will be one of the best ways for selecting target network in heterogeneous wireless networks (4G). MAGD network selection process is predominantly dependent on two steps, i.e., attribute weight, decision maker's (DM's) weight and aggregation of opinion of DMs. This paper proposes Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM) using TOPSIS for the selection of the suitable candidate network. It is scalable and is able to handle any number of networks with large set of attributes. This is a method of lower complexity and is useful for real time applications. It gives more accurate result because it uses Intuitionistic Fuzzy Sets (IFS) with an additional parameter intuitionistic fuzzy index or hesitant degree. MAIFGDM is simulated in MATLAB for its evaluation. A comparative study of MAIFDGM is also made with TOPSIS and Fuzzy-TOPSIS in respect to decision delay. It is observed that MAIFDGM have low values of decision time in comparison to TOPSIS and Fuzzy-TOPSIS methods.

http://dx.doi.org/10.3837/tiis.2016.11.002 **ISSN : 1976-7277**

Keyword: Intuitionistic Fuzzy Sets (IFS), Mobile Node (MN), Decision Makers (DMs), Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM), Multiple Attribute Group Decision (MAGD)

1. Introduction

Recent advancement in communication technology is a driving force behind the mobile and wireless technology adaption rate and popularization over the few decades. To cater the ever increasing clients demand in ubiquitous environment a single technology is not capable to make possible to satisfy the requirements of the clients. A number of different wireless technologies are facilitating to the devices to inherit the multiple-interfaces for available mobile applications today [20]. These devices are free to select any network from the available heterogeneous network environment as per requirements of the applications. Small sizes of devices are playing an important role in adoption of wireless and mobile technologies. Researchers understand the future generation wireless system which will be formed by variety of network integration, i.e., heterogeneous wireless network [33][36]. Thus, it is essential property of future generation wireless systems to support more secure seamless mobility and wide variety of applications and services with different quality of service requirements. There is need of wide range of wireless technologies for incorporating in the emerging and innovative wireless hand held devices. This new development in wireless technology is known as Fourth Generation (4G) wireless technology which facilitates the integration of all technologies and uses IP for the device recognition on the worldwide network [22].

A best known issue for next-generation ad hoc networks is design and implementation of intelligent mobility management techniques which should permit mobile devices to receive seamless switchover services in the worldwide network. In such condition to improve the quality of service, it is essential for the network operators to provide efficient flawless mobility support in the system. Mobility management allows wireless network system to trace roaming devices for communication, also to preserve connection when a device is moving from one technology to another technology region. This process is grouped into location and handoff management processes. A location management technique is dealing with tracking of attachment points of MNs while they are roaming [19]. Further handoff management is a mechanism to provide seamless connectivity in roaming of MNs in the networks of heterogeneous technologies. A handoff event comprises three steps: (i) initiation (ii) decision (iii) execution [17][18]. Initiation phase deals with collection of information about network and users. The selection of candidate network is taken into the decision phase. And finally the execution phase finalizes the handoff. Handoff procedure is categorized as hard or soft handoff. If MN is associated with only one network at a time is called hard handoff. In this approach, connection is first broken from the current point of attachment and then a new connection is established to another point of attachment. It is generally known to as break-before-make approach (BBMA). If MN is connected to two points of attachment during the handoff is known as soft handoff. In this approach a connection to the next point of attachment or base station (BS) is established before releasing the ongoing connection to the current BS or point of attachment. It is generally known as make-before-break approach (MBBA).

A handoff mechanism needs some measurements and information at appropriate time and position when the handoff decision may takes place [1]. It may be considered by a network or MN or collectively by both. In a Network Controlled Handoff (NCHO), a network takes measurement and makes the handoff decision. In a Mobile Controlled Handoff (MCHO), a MN takes its own measurement and MN has main control over handoff decision. When information from a MN is used by a network to take a handoff decision, this approach is recognized as a Mobile-Assisted Handoff (MAHO). When information collected by a network is considered by the MN to take a handoff decision it is known as a Network-Assisted Handoff. In the literature there are many algorithms are available which are considering different parameters. Further a lot of studies are available for vertical handoff for heterogeneous technologies.

A MN frequently undergoes for a network selection when it is being away from the home network. In the heterogeneous wireless network selection of best network for handoff process while to maintaining QoS is a crucial task for the mobile devices. The best available candidate network selection method in heterogeneous wireless networks (4G) is Multiple Attribute Group Decision (MAGD). MAGD network selection process is predominantly dependent on two steps, i.e., attribute weight, DM's weight and aggregation of opinion of DMs.

This paper proposes Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM) which uses TOPSIS for the selecting the suitable candidate network from available heterogeneous wireless networks. The network Selection is based on the attributes with diverse relative importance. It is scalable and is able to handle any number of networks with large set of attributes. MAIFGDM is a method of lower complexity and is useful for real time applications. It gives more accurate result because it uses IFS with an additional parameter intuitionistic fuzzy index or hesitant degree. A comparative study of MAIFDGM is also made with TOPSIS and Fuzzy-TOPSIS in respect to decision delay. It is observed that MAIFDGM have low values of decision time in comparison to TOPSIS and Fuzzy-TOPSIS methods.

The rest of the paper is organized as follows. Section 2 presents the related works. Section 3 describes Intuitionistic Fuzzy Sets (IFSs). Section 4 explores on Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM) using TOPSIS. Section 5 presents analysis of the MAIFGDM based network selection in heterogeneous wireless networks for handoff. Result and discussion of the said scheme are shown in Section 6 and 7 respectively. Finally article is concluded in Section 8.

2. Related Work

The conventional handoff algorithms are considering only a received signal strength indicator (RSSI) criteria. Handoff decision based on only RSS criteria may often cause a ping pong effect. In the heterogeneous wireless environment the handoff may not be only due to weak RSS may also be due to requirement of QoS of the users, mobile device or applications. The process of selecting a best network among the available networks which meets the user preference and application requirement is a challenging task and several algorithms have been proposed in the literature.

In [2] the authors considered the different parameters Received Signal Strength, SINR and adaptive data rate for making the decision. When parameters are all together they improve the end-users QoS. In [12] authors proposed a handoff decision algorithm from WLAN to 3G networks by comparing a existing RSS value and dynamic RSS threshold when point of attachment of MN is WLAN access point. By taking a dynamic RSS threshold, a fake handoff initiations are decreased and a handoff failures remains below a limit.

In [4], [15], a vertical handoff decision works on a cross layer and predictive RSS by using Markov Decision Process (MDP). This method is divided into two phases-(a) predictive RSS is measured and (b) optimal target network is selected. In first segment, a polynomial regression method is used to forecast about the position of the MN whether it moves close to or farther from a network. In second segment with assistance of MDP, a network with minimum charge is selected for handoff. It reduces the unnecessary handoff and balances the load in the target network. The best candidate network is determined by using RSS prediction and MDP analysis. For minimizing the number of handoff failures and unnecessary handoff a handoff decision making method based on travelling distance calculation and distance threshold calculation is proposed in [11][34].

In [16] authors proposed a vertical handoff method for the heterogeneous network comprises of 3G and WLAN. A average RSS is measured continuously by the moving average technique When a MN travels outside of WLAN covering area towards 3G cell, a handoff is triggered. The handoff is initiated only when average of the RSS of WLAN network becomes less than a threshold and calculated lifetime is below or up to handoff delay. Further the life time metric is computed by using the rate of change of RSS and Application Signal Strength Threshold (ASST). When a MN travel towards the WLAN network, the handoff to WLAN is triggered if WLAN facilitates more signal value in comparison of threshold value and fulfils bandwidth requirements of applications. These methods decrease the unnecessary handoff and average throughput increases because when a MN is able to connect to WLAN and may stay connected as long as possible.

In [13] authors proposed a handoff scheme by using a prediction technique based on the parameter RSS. For selection of the most likely candidate BS two different thresholds are used. Location information based handoff algorithm of 3G-WLAN heterogeneous network is proposed in [5] which reduces the handoff time, ping-pong effect and improves the handoff performance. The cost and adaptive functions facilitates the MNs to dynamically adjust some parameters to satisfy the users service requirements in the different environment [6][37].

A vertical handoff is carried out by using adaptive fuzzy logic technique in a heterogeneous wireless network which comprises of diverse access technologies are found in [7]. The metrics viz., data rate, cost, speed of MNs and RSSI parameters are used as input and the outcome is used to decide the handoff event needed or not and to pick the target network. In [8] authors present a new predictive handoff framework which utilizes the neighbor network information to avoid too late or too early handoff executions. In [35][38] authors use neighboring pixels for differentiating the status of the different picture zone and same may be applied on the cellular network for identifying the service status level of different network stations.

In [41] authors by taking into consideration the primary network operator's policies and provide a new network selection and channel allocation mechanism for increasing revenue by accommodating more secondary users and catering to their preferences. This mechanism provides services (QoS at a lower price subject to the interference constraints of each available network with idle channels) to secondary users. It uses particle swarm optimization and a modified version of the genetic algorithm for solving the optimization problem. Authors tried to find a solution which minimizes overall cost for all secondary users and reduces the interference incurred to the primary users of different primary networks.

In [42] authors give an overview of heterogeneous mobile networks, and discuss problems and existing solutions for the coexistence of different wireless protocols, viz.; cellular, broadcast, Wi-Fi, and Bluetooth networks, within the same spectrum band. Cognitive radio technology is used to address the utilization of unlicensed spectrum bands in converged mobile networks [43]. The authors presents existing candidate solutions for the convergence of current wireless standards toward a heterogeneous mobile network scenarios. They also discuss problems regarding the coexistence of the different wireless standards, viz., cellular, broadcast, Wi-Fi, and Bluetooth within the defined band spectrum.

In [40] authors proposed a secure, efficient and dynamic search scheme which constructs a special keyword balanced binary tree as the index, and propose a "Greedy Depth-first Search" algorithm to obtain better efficiency than linear search. This scheme may be applicable for searching the suitable network for handoff in heterogeneous environment. But secure dissemination of handoff data is a big challenge. Scheme proposed in [40] may be useful up to some extent. This scheme uses kNN algorithm for protecting against threat insertion and deletion models. But this scheme suffers in handling the dishonest data user [39].

The Multiple Attribute Decision Making (MADM) technique may be suitable for finding the best network among the available heterogeneous wireless networks which are categorized in terms of their attributes [21]. MADM algorithms provide high precision and fast network selection decisions and have the ability to evaluate multiple criteria simultaneously with medium implementation complexity. Many target network selection MADM techniques available in the literature, viz., Simple Additive Weight (SAW)[3], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)[24], Grey Relational Analysis[25], Multiplicative Exponent Weighting (MEW)[23], ELimination EtChoice Translating REality(ELECTRE) [23]. These methods are suitable for deciding the weights of the attribute set according to network's performance and rank of alternatives networks. In [18] authors proposed a utility function based fuzzy TOPSIS to select energy efficient network. The rank reversal problem was addressed by using the parameterized utility functions. In [14] authors design AHP-SAW mathematical model for network selection in heterogeneous network traffic. But scheme suffers in heterogeneous wired and wireless networks. To provide access of a network in heterogeneous networks, a selection of networks is a complex tasks because a various access technologies having a different characteristics. Thus, there is need of a technique which overcome the above issues and produces minimum network overhead.

3. Intuitionistic Fuzzy Sets (IFSs)

Intuitionistic fuzzy sets (IFSs) are as an extension of fuzzy set (FS) principle [26]. This method is also used in place of fuzzy set for dealing the inadequate information. Fuzzy sets express information using a membership function, but in IFSs, same is expressed by using two additional membership functions, i.e., non-membership degree and hesitation margin.

It is assumed that X is a finite set and IFS A in this set which is mathematically expressed as:

$$A = \{(x, \mu_A(x), v_A(x)) | x \epsilon X\} \quad (1)$$

The functions $\mu_A(x), v_A(x): X \to [0,1]$ are the membership and non-membership functions, respectively. These functions are satisfying the following necessary clause:

$$0 \leq \mu_A(x) + v_A(x) \leq 1 \ \forall \ x \epsilon X$$

Another parameter in IFS is introduced and denoted by $\pi_A(x)$ called as intuitionistic fuzzy index or hesitant degree. This degree arises because of lack of knowledge or error in computing between two fuzzy sets [27]. After introducing the another parameter a intuitionistic fuzzy set A may be represented as

$A = \{(x, \mu_A(x), v_A(x), \pi_A(x)) | x \epsilon X\}$

and

$\pi_A(x) = 1 - \mu_A(x) - v_A(x)$

satisfy following necessary condition:

$$0 \leq \pi_A(x) \leq 1$$

Table 1. Conversion of linguistic term to Intuitionistic fuzzy numbers

Linguistic Terms	**IFNs**
Extremely Good(EG)/ High (EH)	(1.00,0.00,0.00)
Very Very Good(VVG)/ High(VVH)	(0.95,0.05,0.00)
Very Good (VG)/ Very High (VH)	(0.85,0.10,0.05)
Good(G)/High (H)	(0.75,0.15,0.10)
Medium Good (MG)/ High (MH)	(0.60,0.30,0.10)
Fair (F)/Medium(M)	(0.50,0.40,0.10)
Medium Poor(MP)/Low (ML)	(0.40,0.50,0.10)
Poor (P)/Low(L)	(0.25, 0.65,0.10)
Very Poor (VP)/ Low (VL)	(0.10,0.80,0.10)
Very Very Poor (VVP)/ Low(VVL)	(0.05,0.95,0.00)
Extremely Poor (EP)/Low (EL)	(0.00,1.00,0.00)

4. Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM)

The Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM) is suitable for selecting a network for handoff in the presence of uncertainty. This decision method works on the attribute information of relative alternatives an individual decision by decision-makers which is aggregated for taking collective decision. The obtained collective judgments of the decision-makers are used for ranking the alternatives or selecting a best alternative [29]. The spirit of MAGD method is used to pick the suitable alternative from a set of feasible alternatives, which is reflecting most suitable of the group of decision-makers as a whole [30]. In the literature there are a number of MAGD making methods are a proposed [5],[31],[32]. The following steps are used in MAIFGDM TOPSIS method.

Let A, attr and DM are set of alternatives, attributes and DMs, respectively.

$A = \{A_1, A_2, \ldots, A_m\}$, $attr = \{attr_1, attr_2, \ldots, attr_n\}$ and DM $= \{dm_1, dm_2, \ldots, dm_l\}$.

Step1. Construct a intuitionistic fuzzy matrices.
DM individually awards a rating to alternatives in linguistic term by considering the attributes, which can be expressed as

$$r_{ij} = (\mu_{ij}, v_{ij}, \pi_{ij})$$

The decision matrix expressed as follows

$$R^{(k)} = (r_{ij}^{(k)})_{m\times n} = \begin{bmatrix} r_{11}^{(k)} & r_{12}^{(k)} & \cdots & r_{1n}^{(k)} \\ r_{21}^{(k)} & r_{22}^{(k)} & \cdots & r_{2n}^{(k)} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1}^{(k)} & r_{m2}^{(k)} & \cdots & r_{mn}^{(k)} \end{bmatrix} \quad (2)$$

Step 2. Obtain the weights of DMs. Let l DMs are participating in a decision process. It is assumed that an importance of DMs may not be equal and expressed in linguistic terms. Conversion of linguistic term into IFNs is shown **Table 2**. Let $DM_k = (\mu_k, v_k, \pi_k)$ is IFN for assessment of the kth DM . The following relationship is used to compute the weight of DMs [9].

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{l}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)} \quad (3)$$

$$\text{where } \sum_{k=1}^{l}\lambda_k = 1$$

Table 2(a). Linguistic value for DMs and attribute

Linguistic Terms	IFNs
Very important	(0.90, 0.05, 0.05)
Important	(0.75, 0.20, 0.05)
Medium	(0.50, 0.40, 0.10)
Unimportant	(0.25, 0.60,0.15)
Very unimportance	(0.10, 0.80, 0.10)

Table 2(b). Weight of DMs

	Linguistic Term
DM_1	Important
DM_2	Very important
DM_3	Medium

Step 3. Aggregation of intuitionistic fuzzy decisions

Let $R^{(k)}$ denotes intuitionistic fuzzy decision set of the kth DM, importance of each DM is represented by $\lambda = \{\lambda_{1,}\lambda_{2,}\lambda_{3,} \cdots, \lambda_l\}$ and $\sum_{k=1}^{l} \lambda_k = 1$, $\lambda_k \epsilon [0,1]$. An aggregated intuitionistic decision is produced by combining all individual judgment into a group assessment. The following intuitionistic fuzzy weighted aggregated (IFWA) operator combines an individual judgment into group judgment [28].

$$r_{ij} = IFWA_\lambda\,(r_{ij}^{(1)}, r_{ij}^{(2)}, \cdots, r_{ij}^{(l)}) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \cdots \oplus \lambda_l r_{ij}^{(l)}$$
$$= \left(1 - \prod_{k=1}^{l}((1-\mu_{ij}^{(k)})^{\lambda_k}), \prod_{k=1}^{l}((\nu_{ij}^{(k)})^{\lambda_k}), \prod_{k=1}^{l}((1-\mu_{ij}^{(k)})^{\lambda_k}) - \prod_{k=1}^{l}((\nu_{ij}^{(k)})^{\lambda_k})\right) \quad (4)$$

The aggregation of intuitionistic fuzzy decision matrix (IFDM) is as below:

$$R' = (r'_{ij})_{m\times n} = \begin{bmatrix} r_{11}' & r_{12}' & \cdots & r_{1n}' \\ r_{21}' & r_{22}' & \cdots & r_{2n}' \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1}' & r_{m2}' & \dots & r_{mn}' \end{bmatrix} \quad (5)$$

Step 4. Compute the weights of attributes.

Multi-attributes are considered and each attribute may not be of same importance. A grade of importance of attribute is denoted by set W. Thus, the all individual DMs judgment about importance of each attribute is required to be combined.
Let IFN $\omega_j^{(k)} = \left[\mu_j^{(k)}, \nu_j^{(k)}, \pi_j^{(k)}\right]$ is allocated to attribute X_j by the κth DM. Then weight of each attribute is computed by IFWA operator:

$$\omega_j = IFWA_\lambda\,(\omega_j^{(1)}, \omega_j^{(2)}, \cdots, \omega_j^{(l)}) = \lambda_1 \omega_j^{(1)} \oplus \lambda_2 \omega_j^{(2)} \oplus \cdots \oplus \lambda_l \omega_j^{(l)}$$

$$= \left(1 - \prod_{k=1}^{l}((1-\mu_j^{(k)})^{\lambda_k}), \prod_{k=1}^{l}((\nu_j^{(k)})^{\lambda_k}), \prod_{k=1}^{l}((1-\mu_j^{(k)})^{\lambda_k}) - \prod_{k=1}^{l}((\nu_j^{(k)})^{\lambda_k})\right) \quad (6)$$

$$W = [\omega_1, \omega_2, \omega_3, \dots, \omega_j]$$

Table 3. Attribute weights

	DM1	DM2	DM3
$attr_1$	VI	I	VI
$attr_2$	I	I	I
$attr_3$	I	I	M
$attr_4$	VI	VI	I

Step 5. Computing weighted aggregated IFDM.

Further, weighted aggregation IFDM is derived using the aggregated IFDM and weight vector W. It may be expressed as under [26]:

$$R' \otimes W = \{\langle x, \mu_{A_i}(x).\mu_{\omega}(x), \nu_{A_i}(x) + \nu_{\omega}(x) - \nu_{A_i}(x).\nu_{\omega}(x)\rangle | x \epsilon X\} \quad (7)$$

and

$$\pi_{A_i}.\omega(x) = 1 - \nu_{A_i}(x) - \nu_{\omega}(x) - \mu_{A_i}(x).\mu_{\omega}(x) + \nu_{A_i}(x).\nu_{\omega}(x) \quad (8)$$

A weighted aggregated IFDM is as follows:

$$R^{"} = \begin{bmatrix} r^{"}_{11} & r^{"}_{21} & \cdots & r^{"}_{1n} \\ r^{"}_{21} & r^{"}_{22} & \cdots & r^{"}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r^{"}_{m1} & r^{"}_{m2} & \cdots & r^{"}_{mn} \end{bmatrix}$$

Where $r^{"}_{ij} = \left(\mu^{"}_{ij}, \nu^{"}_{ij}, \pi^{"}_{ij}\right) = \left(\mu_{A_{i\omega}}(x_j), \nu_{A_{i\omega}}(x_j), \pi_{A_{i\omega}}(x_j)\right)$.

Step 6. Find the intuitionistic fuzzy-positive-ideal (IFPI) and intuitionistic fuzzy-negative-ideal (IFNI) solutions.

Next step is separate the attribute into benefit and cost attribute. Let J_1 is benefit and J_2 is cost attribute. A^+ is a set of IFPIS and A^- is set of IFNIS. Then A^+ and A^- may be computed as

$$A^+ = \left(\mu_{A^+\omega}(x_j), \nu_{A^+\omega}(x_j)\right) \text{ and } A^- = \left(\mu_{A^-\omega}(x_j), \nu_{A^-\omega}(x_j)\right) \quad (9)$$

where

$$\mu_{A^+\omega}(x_j) = ((\max_i \ \mu_{A_{i\omega}}(x_j)|j\epsilon J_1), (\min_i \ \mu_{A_{i\omega}}(x_j)|j\epsilon J_2))$$

$$\nu_{A^+\omega}(x_j) = ((\min_i \ \nu_{A_{i\omega}}(x_j)|j\epsilon J_1), (\max_i \ \nu_{A_{i\omega}}(x_j)|j\epsilon J_2))$$

$$\mu_{A^-\omega}(x_j) = ((\min_i \ \mu_{A_{i\omega}}(x_j)|j\epsilon J_1), (\max_i \ \mu_{A_i}.\omega(x_j)|j\epsilon J_2))$$
$$\nu_{A^-\omega}(x_j) = ((\max_i \ \nu_{A_{i\omega}}(x_j)|j\epsilon J_1), (\min_i \ \nu_{A_{i\omega}}(x_j)|j\epsilon J_2))$$

Step 7. Compute separation measures.

Further compute the distance measures, SAP_i^+ and SAP_i^-, from each alternative to IFPIS and IFNIS by using the following formula of normalized Euclidean distance

$$SAP_i^{+} = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}[\,(\mu_{A_i\omega}(x_j) - \mu_{A^{+}\omega}(x_j))^2 + (\nu_{A_i\omega}(x_j) - \nu_{A^{+}\omega}(x_j))^2 + (\pi_{A_i\omega}(x_j) - \pi_{A^{+}\omega}(x_j))^2} \qquad [10]$$

$$SAP_i^{-} = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}[\,(\mu_{A_i\omega}(x_j) - \mu_{A^{-}\omega}(x_j))^2 + (\nu_{A_i\omega}(x_j) - \nu_{A^{-}\omega}(x_j))^2 + (\pi_{A_i\omega}(x_j) - \pi_{A^{-}\omega}(x_j))^2} \qquad [11]$$

Step 8. Computing the closeness coefficient.

A relative closeness coefficient of alternative A_i is computed by using the following formula:

$$C_{i^{+}} = \frac{SAP_i^{-}}{SAP_i^{+} + SAP_i^{-}} \quad where\ 0 \le C_{i^{+}} \le 1 \qquad [12]$$

and the rank is decided by arranging the value of $C_{i^{+}}$ in descending order.

5. Analysis

Heterogeneous wireless network comprising of UMTS, WiMax and WLAN is used in the analysis of said method. The DMs- DM_1, DM_2 and DM_3 are engaged to select a best candidate network. Multi attributes are considered to trigger a network selection and these are: 1) available bandwidth, 2) Packet delay, 3) Packet loss and 4) Cost. Three DMs- DM_k (k=1,2,3) are involved and judgment is given in linguistic terms to estimate the rating of networks A_i(i=1,2,3,4) by evaluating for their attributes $attr_j$(j=1,2...4) and prepare a decision matrices $R^{(k)} = (f^{(k)})_{4\times 4}$ (k=1,2,3). Attribute values of considered networks are shown in **Table 4**. The attribute values and ranges shown in this table are collected from different sources in literature. It is observed that there are many versions and upgrades of norms for each technology. For simplicity and wide range of applications it is required to focus on each value of the attributes before finalization of them. Most general values are considered in **Table 4**.

Table 4. Access Network and Attributes

Alternative Networks	Available Bandwidth (Mbps)	Delay (in ms)	Packet Loss	Cost (Unit)
WiMax	1~60	30~100	20~80	.40
WLAN1	1~54	20~150	20~80	.05
WLAN2	1~54	20~150	20~80	.10
UMTS	.1~2	25~200	20~80	.60

Table 5. Assessment of DM1

	$attr_1$	$attr_2$	$attr_3$	$attr_4$
A_1	G	VG	VVG	H
A_2	G	MG	MG	M
A_3	VG	MG	G	MH
A4	MG	G	G	VH

Table 6. Assessment of DM2

	$attr_1$	$attr_2$	$attr_3$	$attr_4$
A_1	VG	G	VG	H
A_2	VG	MG	G	ML
A_3	G	G	MG	M
A4	MG	M	MG	VH

Table 7. Assessment of DM3

	$attr_1$	$attr_2$	$attr_3$	$attr_4$
A_1	VG	G	G	MH
A_2	G	MG	G	ML
A_3	VG	MG	G	M
A4	MG	G	G	H

The analysis of proposed scheme involves several steps which are as under.

Step 1. Create IFDM of each DM.

Evaluation of each DM is shown in **Tables 5-7** in linguistic term. Converting the linguistic decision into IFNs using **Table 3**. The following results are obtained.

$$R^{(1)} = \begin{bmatrix} (0.75,0.15,0.10) & (0.85,0.10,0.05) & (0.95,0.05,0.00) & (0.75,0.15,0.10) \\ (0.75,0.15,0.10) & (0.60,0.30,0.10) & (0.60,0.30,0.10) & (0.50,0.40,0.10) \\ (0.85,0.10,0.05) & (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.60,0.30,0.10) \\ (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.75,0.15,0.10) & (0.85,0.10,0.05) \end{bmatrix}$$

$$R^{(2)} = \begin{bmatrix} (0.85,0.10,0.05) & (0.75,0.15,0.10) & (0.85,0.10,0.05) & (0.75,0.15,0.10) \\ (0.85,0.10,0.05) & (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.40,0.50,0.10) \\ (0.75,0.15,0.10) & (0.75,0.15,0.10) & (0.60,0.30,0.10) & (0.50,0.40,0.10) \\ (0.60,0.30,0.10) & (0.50,0.40,0.10) & (0.60,0.30,0.10) & (0.85,0.10,0.05) \end{bmatrix}$$

$$R^{(3)} = \begin{bmatrix} (0.85,0.10,0.05) & (0.75,0.15,0.10) & (0.75,0.15,0.10) & (0.60,0.30,0.10) \\ (0.75,0.15,0.10) & (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.40,0.50,0.10) \\ (0.85,0.10,0.05) & (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.50,0.40,0.10) \\ (0.60,0.30,0.10) & (0.75,0.15,0.10) & (0.75,0.15,0.10) & (0.75,0.15,0.10) \end{bmatrix}$$

Step 2. DMs weights are calculated. The importance of DMs may not be equal and are shown in **Table 2(b)**. The linguistic terms are transformed into IFNs corresponding to **Table 2(a)**. Further Eq. (3) is used to compute the DMs weight and computed values as follows.

$$\lambda_1 = \frac{0.75 + 0.05\left(\frac{0.75}{0.75 + 0.20}\right)}{\left(0.90 + 0.05\left(\frac{0.9}{0.9 + 0.05}\right)\right) + \left(0.50 + 0.10\left(\frac{0.50}{0.50 + 0.40}\right)\right) + \left(0.75 + 0.05\left(\frac{0.75}{0.75 + 0.20}\right)\right)} = 0.356$$

$$\lambda_2 = \frac{0.90 + 0.05(\frac{0.90}{0.90 + 0.05})}{\left(0.90 + 0.05\left(\frac{0.9}{0.9 + 0.05}\right)\right) + \left(0.50 + 0.10\left(\frac{0.50}{0.50 + 0.40}\right)\right) + \left(0.75 + 0.05\left(\frac{0.75}{0.75 + 0.20}\right)\right)} = 0.406$$

$$\lambda_3 = \frac{0.50 + 0.10\left(\frac{0.50}{0.50 + 0.40}\right)}{\left(0.90 + 0.05\left(\frac{0.9}{0.9 + 0.05}\right)\right) + \left(0.50 + 0.10\left(\frac{0.50}{0.50 + 0.40}\right)\right) + \left(0.75 + 0.05\left(\frac{0.75}{0.75 + 0.20}\right)\right)} = 0.238$$

Step 3. Create an aggregated intuitionistic fuzzy decision matrix.

DMs do the assessments for four alternatives which are given in **Tables 5-7**. All three decision matrices are combined by using the Eq. (5) to produce aggregated intuitionistic decision matrix and obtained matrix is as follows.

$$R = \begin{bmatrix} (0.8201\ 0.1155\ 0.0644) & (0.7916\ 0.1298\ 0.0786) & (0.8855\ 0.0860\ 0.0285) & (0.7205\ 0.1768\ 0.1027) \\ (0.7968\ 0.1272\ 0.0759) & (0.6000\ 0.3000\ 0.1000) & (0.7044\ 0.1920\ 0.1036) & (0.4377\ 0.4618\ 0.1005) \\ (0.8154\ 0.1179\ 0.0667) & (0.6695\ 0.2264\ 0.1041) & (0.6974\ 0.1988\ 0.1038) & (0.5382\ 0.3610\ 0.1008) \\ (0.6000\ 0.3000\ 0.1000) & (0.6687\ 0.2234\ 0.1079) & (0.6974\ 0.1988\ 0.1038) & (0.8306\ 0.1101\ 0.0592) \end{bmatrix}$$

Step 4. Compute the weights of attribute.

In view of DMs the importance of attributes are given in **Table 6**. Eq.(6) is used for determining the weight of attributes and obtained matrix is as follows.

$$W_{(x1,x2,x3,x4)} = \begin{bmatrix} 0.8549 & 0.1325 & 0.0126 \\ 0.7500 & 0.2000 & 0.0500 \\ 0.7053 & 0.2425 & 0.0523 \\ 0.7053 & 0.2425 & 0.0523 \end{bmatrix}^T$$

Step 5. Create a weighted IFDM.

Eq.(7) is used for computing weighted intuitionistic fuzzy decision matrix and obtained matrix is as follows.

$$R'' = \begin{bmatrix} (0.5784\ 0.3300\ 0.0916) & (0.6767\ 0.2451\ 0.0781) & (0.6641\ 0.2688\ 0.0671) & (0.5174\ 0.3936\ 0.0890) \\ (0.5620\ 0.3389\ 0.0992) & (0.5129\ 0.3928\ 0.0943) & (0.5283\ 0.3536\ 0.1181) & (0.3144\ 0.6035\ 0.0821) \\ (0.5751\ 0.3318\ 0.0931) & (0.5724\ 0.3289\ 0.0987) & (0.5231\ 0.3590\ 0.1179) & (0.3865\ 0.5293\ 0.0842) \\ (0.4232\ 0.4697\ 0.1071) & (0.5717\ 0.3263\ 0.1020) & (0.5231\ 0.3590\ 0.1179) & (0.5966\ 0.3444\ 0.0590) \end{bmatrix}$$

Step 6. Find the IFPI and IFNI solutions.

First three attributes viz.; available bandwidth, delay, packet loss are consider benefit and fourth is cost criteria. A IFPI and IFNI solutions are represented by A^+ and A^- , respectively and are given below:

$A^+ = \{(0.5784 \quad 0.3300 \quad 0.0916), (0.6767 \quad 0.2451 \quad 0.0781), (0.6641 \quad 0.2688 \quad 0.0671), (0.3144 \quad 0.6035 \quad 0.0821)\}$

$A^- = \{(0.4232 \quad 0.4697 \quad 0.1071), (0.5129 \quad 0.3928 \quad 0.0943), (0.5231 \quad 0.3590 \quad 0.1179), (0.5966 \quad 0.3444 \quad 0.0590)\}$

Step 7. Estimate the separation measure and closeness coefficient

Euclidean distance is used for measuring the IFPI and IFNI solution for each alternative and closeness coefficient is computed by using Eq.(12) that finds the rank of each alternatives and the results are given below:

Alternatives	SAP_i^+	SAP_i^-	C_{i^+}	Rank
A_1	0.10328	0.12890	0.55517	3
A_2	0.09844	0.15157	0.60626	1
A_3	0.08638	0.12690	0.59500	2
A_4	0.17319	0.03147	0.15377	4

Step 8. Grading/Ranking of the alternatives

The observed alternatives are ranked in decreasing order of closeness coefficient which are as under.

$\mathbf{A_2 > A_3 > A_1 > A_4}$.

6. Simulation

The score of the four alternatives are computed using the TOPSIS method and MAIFGDM using TOPSIS. These scores are used to rank the alternatives. Proposed scheme is simulated using MATLAB. **Fig. 1** shows that the MAIFGDM using TOPSIS really manipulates the ranking of the alternatives. The computed score of the alternative WLAN1 is considerably higher than the alternative WLAN2 (0.6543>0.6354) when TOPSIS method was in place. But the scores of these two alternatives when computed by the MAIFGDM using TOPSIS are nearly equal, i.e., (0.60626~0.5950). This behavior is because of the aggregation of judgments of DMs which moderates in difference of score. Thus, the proposed method avoids unnecessary handoffs. The same pattern is seen by comparing the score of the alternatives WLAN2 and WiMAX. By using the TOPSIS method, the score of WLAN2 alternative is significantly higher than the WiMAX alternative (0.48017>0.36125) while the score computed by MAIFGDM using TOPSIS are very close (0.60626>0.5517). This difference is observed because in MAIFGDM using TOPSIS method, each criterion is ranked by DMs and their judgments are further aggregated. The impact of proposed method's of the closeness to the IFPIS and IFNIS in comparison of TOPSIS [24].

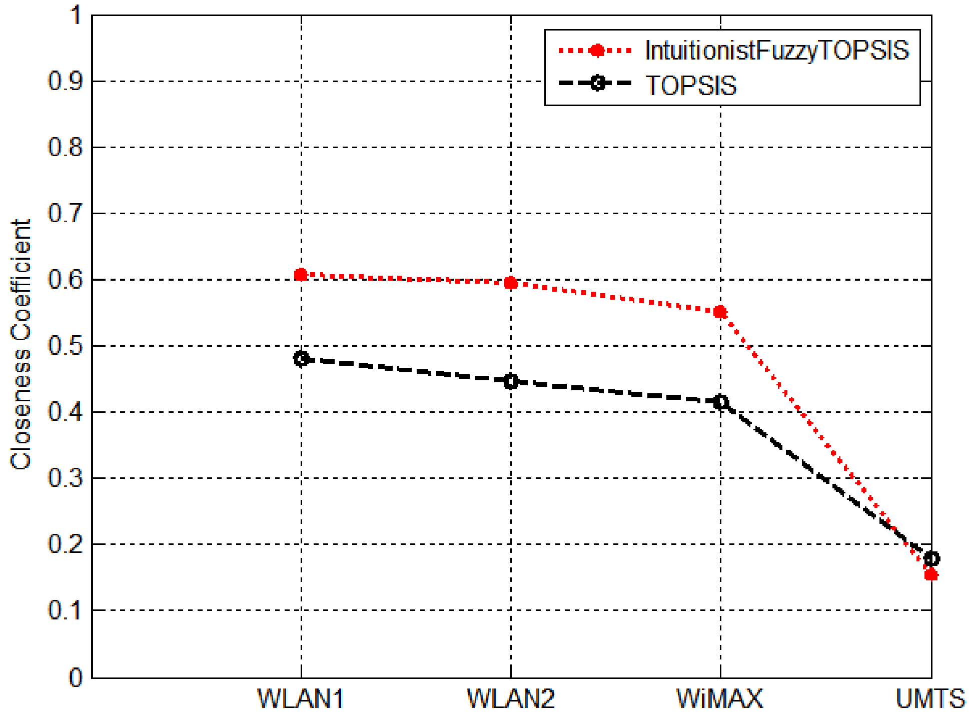

Fig. 1. Comparison of Proposed method with TOPSIS for Video Application

Similarly the relative closeness coefficients for each alternative according to users' applications are computed and are shown in **Table 8**. **Figs. 2(a)-2(d)** disclose that for the real-time applications, viz., voice and video conversations WLAN and WiMAX are ranked much higher than UMTS. This situation arises due to substandard packet delay features and poor available network bandwidth of UMTS network. In simulation particularly when voice conversation is considered the higher WiMAX reparation is seen for this network and it was very close to WLAN2. The numerically observed values are nearly equal scored (0.5813) with WLAN2 (0.5955). Since the requirement of low network bandwidth for voice application has relative importance with respect to the real-time video application. Results show that the said method meets the requirement of QoS of the system.

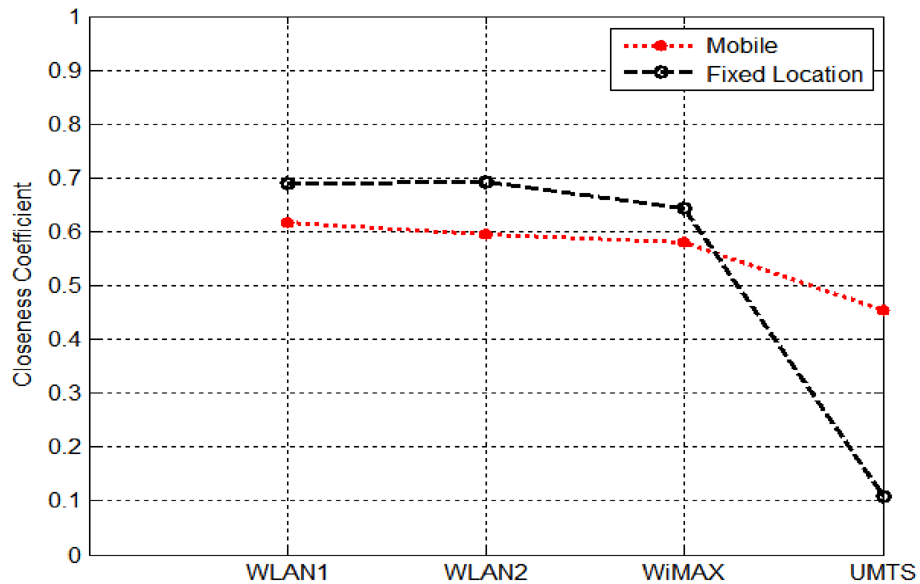

Fig. 2(a). Voice Application

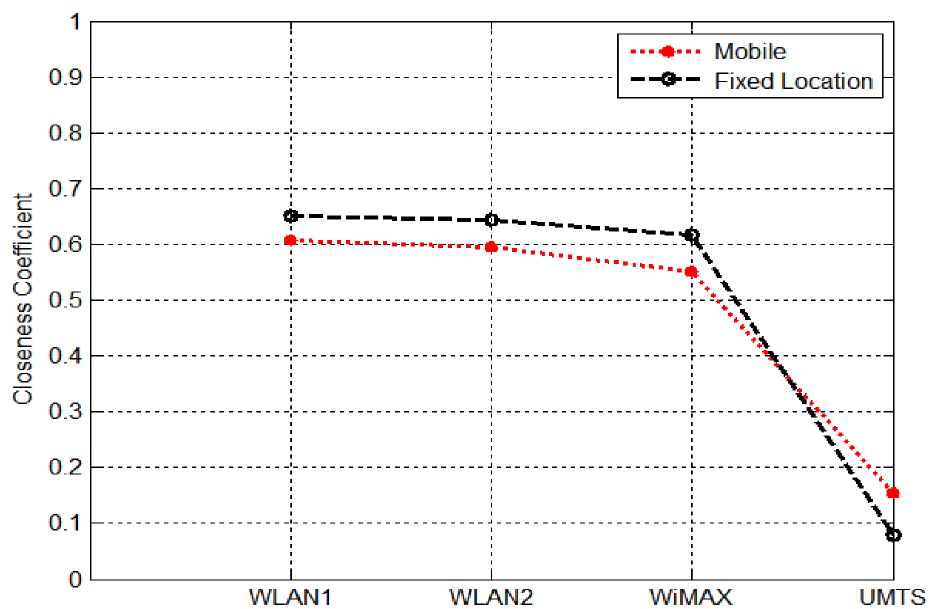

Fig. 2(b). Video Conferencing Application

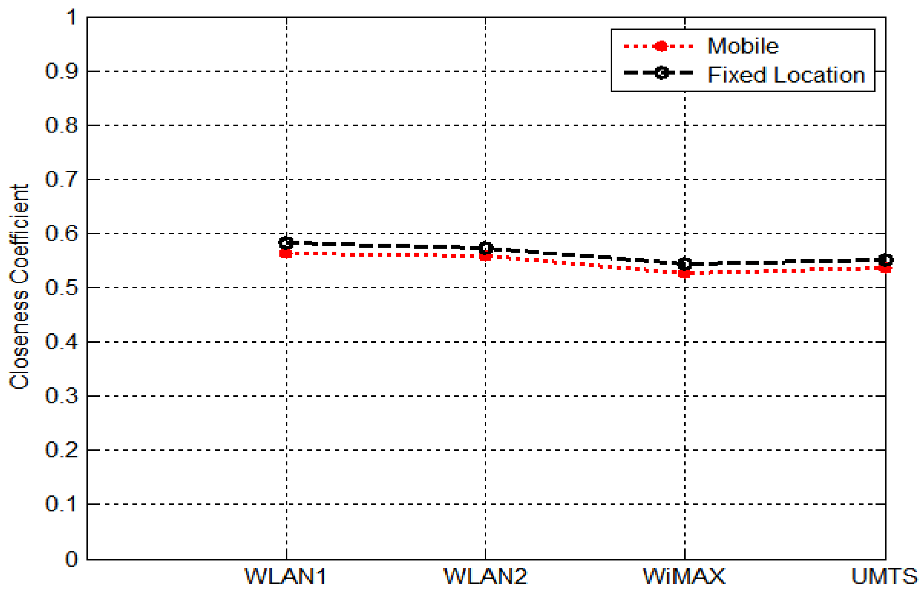

Fig. 2(c). Video Streaming Application

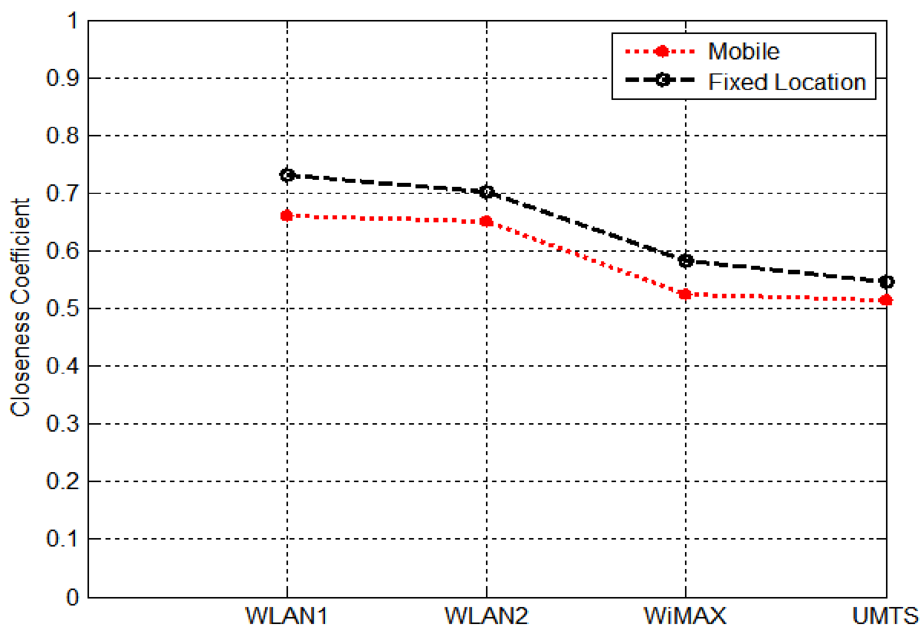

Fig. 2(d). Web Browsing Application

Further, when non-real-time applications are considered, viz., video streaming and web browsing, UMTS score is much higher than real-time applications. This happens because their QoS features may not be considered beyond the minimum acceptable QoS limits. It is also observed that the scores of all four alternatives are very close to each other because usefulness of their QoS features is virtually very close to each other. Especially, the scores of alternative networks are even closer when a user runs applications in fixed location. This feature is considerable in the design of the handoff triggering process. When scores of alternative networks are very close unnecessary handoffs are avoided which avoids waste of network resources.

Table 8. Application based closeness coefficient

		WLAN1	WLAN2	WiMAX	UMTS
Voice	Mobile	0.61626	0.5955	0.5813	0.45377
	Fixed Location	0.688565	0.692369	0.643721	0.108107
Video Conference	Mobile	0.60626	0.595	0.5517	0.15377
	Fixed Location	0.650176	0.642369	0.617208	0.078107
Video Streaming	Mobile	0.60626	0.597	0.5317	0.55277
	Fixed Location	0.670175655	.643688	0.59372	0.58606
Web Browser	Mobile	0.62626	0.6095	0.5217	0.50377
	Fixed Location	0.560064	0.551523	0.49154	0.471561

Decision delay using the classical TOPSIS and Fuzzy-TOPSIS methods was discussed in [44]. But in **Fig. 3** a comparative study is made for TOPSIS, Fuzzy-TOPSIS and MAIFDGM methods in respect to decision delay. It is observed that MAIFDGM have low values of decision time in comparison of TOPSIS and Fuzzy-TOPSIS methods. TOPSIS method always computes fresh weight matrices for every available network. But, Fuzzy-TOPSIS is a less complex method. MAIFDGM may be considered as method of lower complexity and is useful for real time applications. It is more accurate method because it uses IFS with an additional parameter intuitionistic fuzzy index or hesitant degree. This degree arises because of lack of knowledge or error in computing between two fuzzy sets.

Figs. 4(a-b) show that score of UMTS network is near to zero or zero for real application. The value near to zero or zero means there is no network connection available and in progress call will be dropped or very large delay will be observed. The simulation result for the MAIFGDM algorithm presented in **Figs 2(a-b)** show that UMTS score is much lower than the WLAN and WIMAX in case of real applications and it is due to packet delay characteristic in both the situations (mobile and Fixed). But in MAIFGDM algorithm this is not zero in case UTMS for real applications. Thus, it is observed from **Figs. 2(a-b)** and **Figs. 4(a-b)** that MAIFGDM algorithm performs better in comparison to [18].

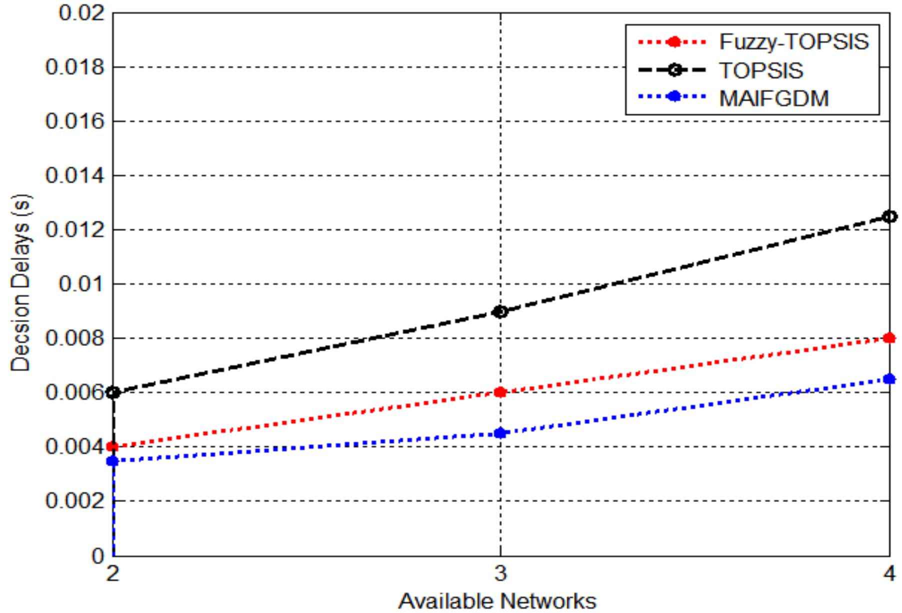

Fig. 3. Decision delay for different Networks

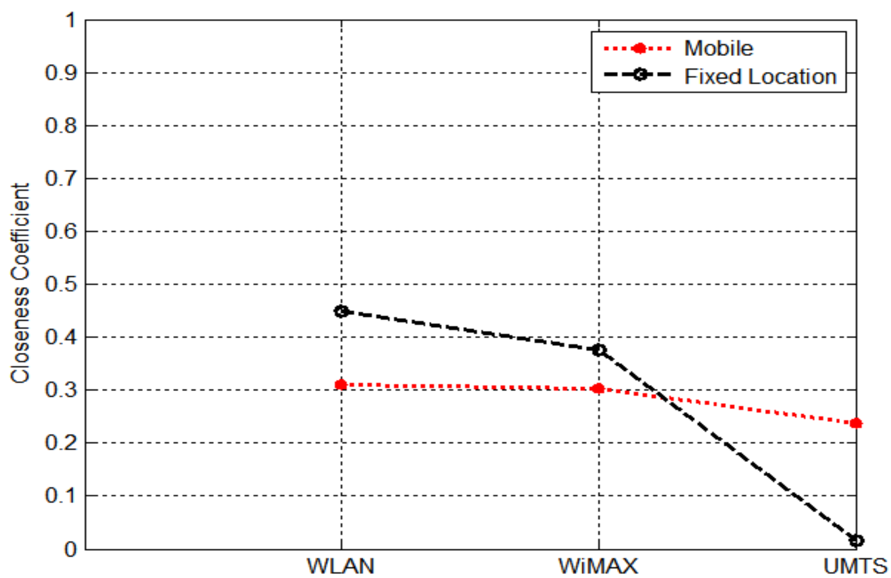

Fig. 4(a). Voice Application[18]

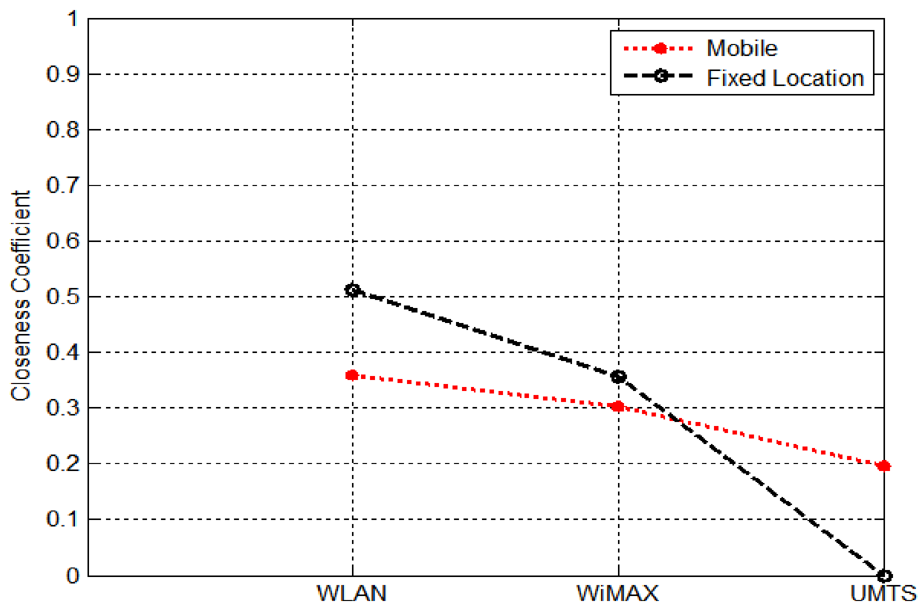

Fig. 4(b). Video Conferencing [18]

7. Discussion

In this paper a MAIFGDM using TOPSIS for selecting a network for handoff in the presence of uncertainty is proposed. This method uses Intuitionistic fuzzy TOPSIS for studying the behavior of multiple attributes in the selection process. The analysis of MAIFGDM proves that how many attributes in resolution making along with a group of DMs who are participating in the decision making process. The outcome indicates that network selection from a set of network for handoff is a multi-criteria concept and developed scheme does it easily. Further study shows that key network selection must be aware that the handoff decision making is not just a black box. The proposed scheme is able to capture a fairly complete picture of the networks available before decision making process is initiated. The complication arises as the number of criteria increases and network selection attributes takes with some sort of uncertainty. Since, there are various ways to study fuzziness which arrive in the network selection for handoff. Thus, there are different mathematical model which may be used by many researchers and have shown that IFS is an appropriate which deals with the uncertainties is the case here.

In assessment process, the grading of each alternative on the basis of attributes and their weights which is characterized by linguistic terms and further converted into IFNs. Also IFWA operator is used for aggregating the judgment of different DMs. After IFPI and IFNI solutions are computed by using Euclidean distance formula, the closeness coefficients of alternatives are computed and alternatives are ranked. To show how DM’ judgment in uncertain form may be considered, at the time of decision making. Scheme is numerically analyzed four alternatives for four attributes where decisions from three DMs are obtained. In [18] the value near to zero or zero means there is no network connection available and in progress call will be dropped or very large delay will be observed. The simulation result for the MAIFGDM algorithm show that UMTS score is much lower than the WLAN and WIMAX in case of real applications and it is due to packet delay characteristic in both the situations (mobile and Fixed). But in MAIFGDM algorithm this is not zero in case UTMS for real applications. Results indicate that the proposed scheme is reasonable and determines an optimal choice among four possible alternatives.

8. Conclusions

In this article we have proposed Multi-Attribute Intuitionistic Fuzzy Group Decision Method (MAIFGDM) which uses TOPSIS for the selecting the suitable candidate network from available heterogeneous wireless networks. The network Selection is based on the attributes with diverse relative importance. In assessment process, it uses the grading of each alternative on the basis of attributes and their weights which is characterized by linguistic terms and further converted into IFNs. It is observed that judgment of DMs about each alternative by considering the each attribute and weight of each attribute are given as linguistic value characterized by IFNs. Further it uses an IFWA for aggregating the judgment of different DMs. After IFPI and IFNI solutions are computed by using Euclidean distance formula, the closeness coefficients of alternatives are computed and alternatives are ranked. The outcome indicates that network selection from a set of network for handoff is a multi-attribute concept and developed scheme does it easily. The combined approach TOPSIS with IFS may enormous chance of success of multi-attribute decision-making solution because of vague perception of DM's judgment. Thus, IFSs may be utilized for dealing with uncertainty in multi-attribute decision-making problems such as network path selection. This method is scalable and is able to handle any number of networks with large set of attributes. MAIFGDM is a method of lower complexity and is useful for real time applications. It gives more accurate result because it uses IFS with an additional parameter intuitionistic fuzzy index or hesitant degree. Results show that MAIFDGM have low values of decision time in comparison to TOPSIS and Fuzzy-TOPSIS methods.

Now, we are in the process of examining the complete handoff solution for heterogeneous wireless network using the proposed network selection method. This process will facilitate seamless handoff and will reduce the ping-pong effect. Further, this method will be tested with the help of mobile agent technology [45] over real life heterogeneous wireless networks.

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