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QoS and Cost-Aware Protocol Selection for Next Generation Wireless Network

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Abstract

In the growing area of Internet of Things (IoT), mobility management protocols become necessary because in today's environment everything is movable so there is no dominance of static nodes. Mobility is a key aspect for the next-generation wireless network. So, mobility management mechanism is necessary for providing the seamless handoff to end user regardless of their location. Thus, Internet Engineering Task Force (IETF) has developed the Mobile IPv6 (MIPv6) for providing the mobility facility. But MIPv6 is not able to provide the mobility for next-generation wireless network due to large packet loss and high latency. Thus, Proxy MIPv6 (PMIPv6) is developed for providing the mobility for the next-generation network, but it has some limitation as well. In this paper, firstly a survey of various types of protocols based on PMIPv6 protocol is given. Then protocol is selected based on the Quality of Service (QoS) and signaling cost parameters. Two applications are considered i.e. streaming and background traffic class. For streaming traffic class, QoS (handoff latency) parameter is preferred and for background traffic class, signaling cost is preferred. Analytical Hierarchical Process (AHP) method is used for assigning the weight of different traffic class because user`s preferences play an important role in the decision-making process as it enhances the quality of experience of the user. Then multi-attribute decision making (MADM) and prospect theory are used for selection of protocols. Results show that different protocols are selected for different applications. The performance of MADM and prospect theory is shown in terms of accuracy.

Keywords MADM algorithm · Mobility Management protocols · Prospect theory · Proxy Mobile Internet Protocol version 6 (PMIPv6) · Seamless handoff

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1 Introduction

For 5G wireless networks, there is a need of larger capacity and high mobility for fast-moving vehicles. The cell densification in the 5G network is required for high capacity support for low mobility users. For next-generation networks, mobility for vehicles communication becomes necessary [1]. The mobility management is required for seamless access to mobile services. The basic need of mobility management is for supporting mobility for all types of real and non-real applications across homogeneous and heterogeneous wireless network without interruption of the ongoing session. The session should be continued when the user moves from one access point to another access point. Mainly, mobility management consists of two steps: location management and handoff management [2]. The location management takes care of Mobile Node (MN) reachability in every location and it should be always connected to the network. The handoff management takes care of active session which should be maintained at the time of MN roaming [3].

For providing the full access to information and to move from one network to another, mobility management protocols are required [4]. For achieving consistent and efficient handoff process of different mobile nodes, initially, Mobile Internet Protocol version 4 (MIPv4) was proposed by Internet Engineering Task Force (IETF). Then MIPv6 is designed to overcome the problems of MIPv4 such as weak security mechanism and small size of IP address. MIPv6 support 128 bit long integers and it support mobility for next-generation networks [5]. MIPv6 protocol which is a host-based mobility management protocol, provide continuous service to Mobile Nodes (MNs). For high mobility application, MIPv6 does not provide best services because, at the time of handoff, it creates disruption. For removing the drawback of MIPv6, the IETF Network-based Localized Mobility Management (NETLMM) developed another type of protocol which is called Proxy Mobile IPv6 (PMIPv6). It is network-based mobility management protocol which has various advantages as compared to MIPv6 such as lower handoff latency and does not perform Duplicate Address Detection (DAD). PMIPv6 protocol suffers from packet ordering and packet loss problem. So to overcome the problem of PMIPv6, several improved approaches are developed for seamless handoff [6].

In literature [7–9], different protocols are studied but it is not defined anywhere that which protocol is suitable for the specific application. As there exists a large number of protocols, so it becomes a difficult task to select the best protocol according to user's requirement. In this paper, a brief description of several mobility management protocols is given for handoff procedure improvement. Every protocol has its own procedure for performing the handoff process [10] and has different advantages and disadvantage in terms of different QoS and signaling cost parameter [6]. The different protocols are analyzed based on the handoff latency and signaling cost. Then selection of protocol is done for different application based on user's requirement that enhances the QoE. As the 5G wireless network is based on increasing user`s QoE, so user preferences should be taken into account for selection. The user can give preference by AHP method according to their requirements. Therefore, AHP based selection gives optimal and efficient results on the basis of application requirements. Then MADM and prospect theory are used for selection of best protocol according to the specific applications. As there are different methods for selection, but here two methods are used for validation of results. The selection results are equally valid for high mobility and next-generation wireless network. Finally, accuracy has been used as the performance metric.

The weight for different protocols parameters are computed by AHP [11]. The weight can be calculated by subjective and objective methods. In the subjective weight calculation method, user preference is considered while in the objective method, user preference is not considered. AHP method is termed as subjective method because the user can give preference according to their requirement.

The protocol selection problem in heterogeneous environment is simulated by MADM algorithm and prospect theory. Different MADM algorithms include Simple Additive Weighting (SAW), Multiplicative Exponential Weighting (MEW), Grey Relational Analysis (GRA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and VIKOR (VlseKriterijumska Optimizacijia I Kompromisno Resenje, in Serbian) are used for score calculation [12, 13]. In MADM algorithm, the selection is done on the basis of user's preferences and the user always tries to maximize their utility so their decision may lead to inefficient performance [14]. However, MADM methods are known to suffer from ranking abnormalities, which may result in the ranking variation of alternatives when an alternative/protocol is added or removed [15].

The prospect theory was proposed to overcome the drawback of expected utility theory [16]. It is a behavioral economic theory which is used for decision making under risk. The prospect theory is well applied in the field of economics but in the wireless communication, it is not well developed. MADM algorithm is also used for decision making but in these methods, risk factor is not considered [17]. There may be risk that a wrong protocol is selected by the user but this factor cannot be considered in the MADM algorithm. This risk factor is considered in the prospect theory.

The remainder of this paper is organized as follow: Sect. 2 introduces the different mobility management protocols. In the Sect. 3, AHP method for weight calculation is discussed. Sections 4 and 5 describes the score calculation using MADM algorithm and prospect theory respectively. Section 6 describes the performance metrics. In Sect. 7, simulation results using weight calculation and score calculation for different applications are discussed. Finally, in Sect. 8, the conclusion is given.

2 Mobility Management Protocols

In early 2000, various mobility management protocols were proposed. Some of the protocols are host-based, which require an active participation from the MN while some protocols are network based in which another entity is the responsible for mobility instead of MN [10]. PMIPv6 protocol is network-based mobility management protocol developed by IETF [18]. In any IP based mobility signaling, it provides mobility without the need of MN. Movement of MN is tracked by mobility entities which are present in the network. The mobility signaling is initiated by it and then it set the required routing state.

The main blocks involved in mobility management is Mobile Access Gateway (MAG) and Local Mobility Anchor (LMA). MAG act as an access router which keeps track the movement of MN and manages the signaling of MN mobility. The MN routes are maintained by LMA. LMA is an agent gateway which is in charge of mobile node's prefix and manages the mobile node's binding state. As shown in Fig. 1, if the mobile node moves from home network to another network, then its movement is detected by MAG1. MAG1 is the previously attached MAG and MAG2 is the new one when MN moves to a closer position. MAG1 send the Proxy Binding Update (PBU) to LMA for deregistering the state of MN. After receiving the PBU, LMA deletes the Binding Cache Entry (BCE) and send the Proxy Binding Acknowledgement (PBA) to MAG1. At the same time, the MN is detected by MAG2 in its network range and it sends PBU to the LMA for new state registration of MN. A bidirectional tunnel is established between LMA and MAG2. Then, the packets are transferred through the new PMIPv6 tunnel to destination MN. In PMIPv6, there is no involvement of MN and if there is any tunneling overhead, then it is removed from the air. During the handoff process, if the MN is not able to transmit and receive packets, then there exists some delay. So, PMIPv6 suffer from handoff latency and packet loss. To overcome the drawback of PMIPv6 protocol, different protocols are developed. A brief introduction of these protocols is given here.

2.1 Fast Handoff in PMIPv6 (FH-PMIPv6)

To overcome the drawback of PMIPv6 protocol such as large handoff latency and packet loss, Fast handoff in PMIPv6 is applied. The handoff performance is improved in FH-PMIPv6, mainly in that highway scenario in which MN's movement

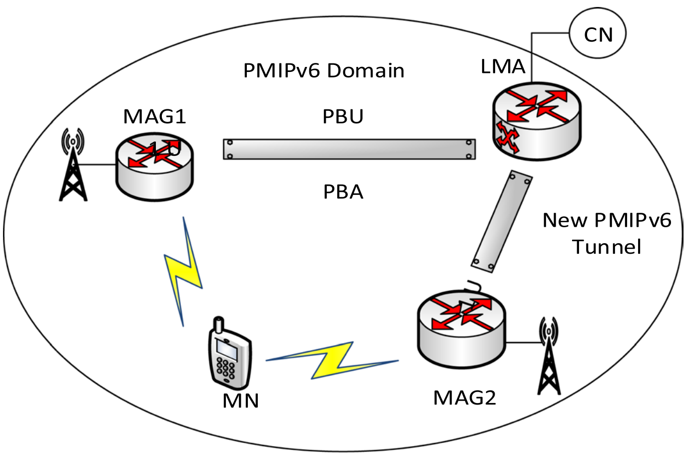

Fig. 1 PMIPv6 mobility management protocol

is in quasi-one Dimensional (1D) and Base Station (BS) is in 1D space. In that case, chances of anticipated handoff are increased [6]. However, FH-PMIPv6 also has some drawback such as false handoff initiation which causes unnecessary handoff and extra signaling between MAG1 and MAG2.

2.2 Hybrid Mode Fast Handoff for PMIPv6 (HF-PMIPv6)

To overcome the drawback of PMIPv6 and FH-PMIPv6 scheme, a hybrid mode fast handoff for PMIPv6 (HF-PMIPv6) is introduced [6]. HF-PMIPv6 has the advantage of smaller handoff latency and packet loss as compared to PMIPv6 and FH-PMIPv6 while there is no additional cost as compared to FH-PMIPv6. In HF-PMIPv6, a decision table is used for detection of mobility mode. The mobility mode can be reactive and predictive. In the reactive mobility mode, the handoff is directly performed without a tunnel setup. So this mode has the advantage of reducing tunnel transmission cost, signaling cost, and handoff latency. In the predictive mobility mode, a tunnel is established such as in PMIPv6 between MAG1 and MAG2 for reducing packet loss. In HF-PMIPv6, buffer mechanism is used for avoiding the packet losses and it performs authentication and registration process simultaneously through which handoff latency is reduced [19].

2.3 Fast Localized Proxy Mobile IPv6 (FL-PMIPv6)

The FL-PMIPv6 protocol is the host-based mobility management protocol in which handoff process is initiated by the MN. The basic idea of FL-PMIPv6 is taken from Fast-Handovers for Mobile-IPv6 (FMIPv6) and it uses message format of 802.21. By using the MIH message signal, MN gives information to the next MAG before starting the handoff process. Handoff related signal is sent from MAG1 to MAG2 [8]. If the handoff process is timely and correctly predicted, then packet loss can be reduced. The handoff prediction time is approximately few tens of millisecond. This scheme has the advantage of less packet loss and reduced handoff latency.

2.4 Packet Lossless PMIPv6 (PL-PMIPv6)

PL-PMIPv6 is an analytical model which is designed for lossless data traffic with authentication consideration. In this model, MAG1 do registration of MAG2 with LMA in advance which has the advantages of reduced handoff latency. After that for reducing packet loss, buffering mechanism is used by MAG2. Sometimes various data packets are lost because before receiving the PBA, no data is accepted by MAG2 [20]. The complete handoff success is depending upon the correct judgment of MAG1 in which mobile nodes are traveling. PL-PMIPv6 has the advantage of less cost.

2.5 Mobile Node's Home Network Prefix (MN-HNP) Based PMIPv6

In PMIPv6, a prefix is allocated for link between MN and MAG which is known as MN-HNP. There can be more than one prefix which can be allocated for link between MN and MAG but in these cases, all prefixes are handled as a group related with the mobility session. The prefix length can be 128-bit in some configuration. In this scheme, MN related information MN-HNP (MN-identifier) is stored in Authentication, authorization, and accounting (AAA) server by which MAG2 can access to that information after the re-association message from the MN via the access point. If MN connects to PMIPv6 using different interfaces at the same time, then every interface is allocated a different set of HNP. The entire prefix is allocated to unique interface of MN which is handled with one mobility session. The MN constructs its interface with their address by using HNP [9].

2.6 Proxy Mobile IPv6-Multicast Handoff Agent (PMIP-MHA)

For seamless handoff, fast attachment to new MAG becomes necessary. So for fast neighbor MAG attachment and reducing the unnecessary data transmission during the handoff procedure, multicast handoff agent is proposed which is known as PMIP-MHA. In PMIP-MHA, list of an active mobile node in all groups is maintained by every MHA cache which helps in fast joining during the handoff procedure. For handoff, two triggers are taken i.e. Link Detected (LD) and Link Up (LU). When LD signal is detected then mobile nodes send proxy Multicast Link Detection (MLD) signal to MAG1 for preregistration before the handoff. After receiving MLD signal, MHA of MAG1 update its cache and helps in fast joining during the handoff procedure [21].

2.7 Smart Buffering Scheme

In PMIPv6, the smart buffering scheme is proposed for reducing data traffic loss and providing the seamless handoff. In this scheme, MN participation is not considered while Received Signal Strength (RSS) is measured on network side for handoff purpose and a discovery mechanism is used for finding the next MAG. Smart buffering scheme eliminates the redundant packet transmission by using the link layer retransmission indication and large buffering time [22]. Thus, the smart buffering scheme has the advantage of small packet loss ratio, small latency and avoid redundant packet transmission but transmission cost of buffered data is high. For identifying the MAG2 and forward procedure between MAG1 and MAG2, an additional signal is used, so this scheme also causes signal traffic overhead.

2.8 Head MAG

Head MAG provides more reliable handoff as compared to other schemes. MAG maintains the MN's mobility information in the head MAG. The advantage of head MAG is fast handoff and fewer traffic losses. The head MAG is that MAG which is located in the same LMA domain at an optimal position. All the MAG's address information is maintained in the Head MAG which updates MN new location in MAG2. This procedure has the advantage of fast handoff and fewer traffic losses but has the drawback of additional overhead and infrastructure cost. It also caused extra signaling cost and transmission cost due to additional message signal and increasing buffering traffic from MAG1 to MAG2 respectively [23].

A summary of major aspects, advantages and disadvantages of each of the protocols as identified in this section, is illustrated in Table 1.

3 QoS and Cost Weighted Parameters

The AHP method is used for assigning the weight of QoS and cost aware protocol. This weight calculation method is generally used and it is developed by Saaty [11]. Therefore, for selection of a protocol, it is used to provide preference weight to each parameter on the basis of user`s preference It consists of different steps for weight calculation:

Step 1: Construct an ordered structure: First of all, the objective of the problem i.e. QoS and cost parameters are defined in terms of different parameters. Then the protocol selection problem is broken down into an ordered structure where at the middle level, parameters are placed and at a lower level, protocols are placed.

Step 2: Construct comparison matrix: The pairwise comparison matrix is given by $L = \left[l_{mn}\right]_{i \times i}$ where i is the total number of protocols and $l_{mm} = 1, l_{mn} = 1/x_{nm}, l_{mn} \neq 0$. The element l_{mn} is defined by Saaty's scale from 1 to 9 values as shown in Table 2. The Saaty's scale number is given corresponding to their importance of one parameter to another.

Step 3: Construct normalized matrix: For scaling the attribute in the same scale, there is a need for normalization [34]. The matrix is normalized by:

$$k_{mn} = \frac{l_{mn}}{\sum_{m=1}^{i} l_{mn}} \tag{1}$$

Step 4: Calculate of relative weights: After normalization, the weights of different parameters are calculated by:

$$w_m = \frac{\sum_{m=1}^{i} k_{mn}}{i} \quad \text{where} \quad \sum_{m=1}^{i} w_m = 1 \tag{2}$$

where i denotes the number of parameters.

Table 1 Summary of different protocols

Protocol	Major Aspects	Advantages	Disadvantages
FH-PMIPv6 [24]	Improve handoff performance in highway scenario	Reduce the handover latency and the packet loss ratio as compared to PMIPv6	False handoff initiation which causes unnecessary handoff Extra signaling between MAG1 and MAG2
HF-PMIPv6 [25]	A decision able is used for detection of mobility mode (reactive and predictive) Buffer mechanism is used for avoiding the packet losses	Reduce tunnel transmission cost and signaling cost Reduced spent time on DAD procedure as compared to FH-PMIPv6	In predictive mode, a tunnel will be established which increase handoff delay
FL-PMIPv6 [26]	Host-based mobility and initiated by MN The network access devices need to perform L2 intelligently.	Reduce the handoff latency and packet loss as compared to FH-PMIPv6 and HF-PMIPv6	Increase burden on MN
PL-PMIPv6 [27]	MAG1 do registration of MAG2 with LMA in advance	Reduce handoff latency Less cost	For information transfer, wait for PBA from MAG2 Data sent before PBA is rejected
MN-HNP [28]	A prefix is allocated for link between MN and MAG MN constructs its interface with their address by using HNP	Large buffer capacity have made the proposed scheme cost-effective Reduce the packet loss	Increase overhead cost
PMIP-MHA [29]	List of an active mobile node in all groups is maintained by every MHA cache which helps in fast joining during the handoff procedure Two triggers are taken i.e. Link Detected (LD) and Link Up (LU).	Reduce the unnecessary data transmission Support the fast neighbor attachment Minimize handover delay	Less security Need an additional cache which increases the cost
Smart buffering [30]	MN participation is not considered RSS is measured on network side for handoff purpose and a discovery mechanism is used for finding the next MAG	Reduce data traffic loss Small packet loss ratio and small latency Avoid redundant packet transmission	Transmission cost of buffered data is high Increase signal traffic overhead
Head MAG [31, 32]	All the MAG's address information is maintained in the head MAG which updates MN new location in new MAG	Fast handoff Fewer traffic losses	Additional overhead and infrastructure cost Extra signaling cost and transmission cost

Table 2 Saaty's scale of pairwise comparison [33]

Saaty's scale	Relative importance of two sub-elements
1	Equally important
3	Moderately important with one over another
5	Strongly important
7	Very strongly important
9	Extremely important
2, 4, 6, 8	Intermediate value

4 MADM Algorithm

MADM methods are the most commonly used method for solving the selection problem. Different MADM algorithms include SAW, MEW, TOPSIS, VIKOR, and GRA are used for ranking of protocols.

4.1 SAW (Simple Additive Weighting)

The SAW is the simplest method for selection of different alternatives. For selection purpose, firstly arrange the parameters range in one scale by normalization. Then the score of different alternatives is calculated by adding the weighted product of all the parameter [35]. The score obtained by the SAW method is given by

$$S_{SAW} = \underset{m \in I}{argmax} \sum_{n=1}^{j} w_n a_{mn} \tag{3}$$

Where w_n are the weights of different parameters and a_{mn} is the normalized matrix of different parameters. In this paper, the normalization is done by

$$a_{mn} = \frac{U_{minimum}}{U_{mn}} \quad m = 1, 2, \ldots \ldots in = 1, 2, \ldots \ldots j \tag{4}$$

Here U_{mn} is the nth parameter matrix of mth protocol.

4.2 MEW (Multiplicative Exponential Weighting)

MEW is another simplest MADM method in which the normalized parameters matrix is powered by w_n. It is also known as the weighted product method. The alternative which has the highest score is selected as the optimal solution [13]. The scores for mth alternative is obtained by

$$S_{MEW} = \underset{m \in I}{argmax} \sum_{n=1}^{j} a_{mn}^{w_n} \tag{5}$$

where a_{mn} denotes the normalized matrix obtained by using Eq. (4) and w_n denotes the weight of n^{th} parameters.

4.3 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS is also an MADM method which is used for measuring relative efficiency of different protocol. In this method, the preference order is determined on the base of best similarity to positive choice and worst similarity to negative choice [15].

Step 1: Firstly, the decision matrix is defined in normalized form for one scale transformation by using Eq. (6).

$$r_{mn} = \frac{U_{mn}}{\sqrt{\sum_{m=i}^{i} U_{mn}^2}} \tag{6}$$

Step 2: Then, the weights for different parameters are multiplied to the normalized matrix.

$$v_{mn} = w_m * r_{mn} \tag{7}$$

Step 3: After that the positive and negative ideal solution is determined. The positive ideal solution maximizes the benefit parameter and negative ideal solution minimize the cost parameter.

$$v_n^+ = \{(\max_{m \in i} v_{mn} \,| n \in N, (\min_{m \in i} v_{mn} | n \in N')\} \tag{8}$$

$$v_n^- = \{(\min_{m \in i} v_{mn} \,| n \in N, (\max_{m \in i} v_{mn} | n \in N')\} \tag{9}$$

where N is the set of benefit parameters and N′ is the set of cost parameters.

Step 4: In this step, determine the distance from different alternatives to positive and negative ideal solution by Eq. (10) and (11).

$$S_m^+ = \sqrt{\sum_{n \in j} (v_{mn} - v_n^+)^2} \tag{10}$$

$$S_m^- = \sqrt{\sum_{n \in j} (v_{mn} - v_n^-)^2} \tag{11}$$

Step 5: The relative closeness to the ideal solution is calculated by Eq. (12) and finally arranges the alternatives in the decreasing order for calculation of scores of different protocols.

$$C_j = \frac{S_m^-}{S_m^- + S_m^+} \tag{12}$$

4.4 VIKOR

VIKOR method was developed for a complex system for achieving the multi-attribute optimization. It is able to determine a compromise ranking list. Even in the presence of conflicting criteria, it just focuses on ranking and selecting the optimal alternative [14]. Firstly, the positive and negative ideal solution is determined by Eq. (8) and (9). Then, calculate S_m and R_m for $m = 1, 2, \dots \dots, i$ by using the Eq. (13) and (14).

$$S_m = \sum_{n \in j} w_n \frac{\left(v_n^+ - a_{mn}\right)}{\left(v_n^+ + v_n^-\right)} \tag{13}$$

$$R_m = \max_{n \in j} w_n \frac{\left(v_n^+ - a_{mn}\right)}{\left(v_n^+ + v_n^-\right)} \tag{14}$$

After that calculate D_m for each $m = 1, 2, \dots \dots, i$ by Eq (15)

$$D_i = \gamma \left(\frac{S_m - S^+}{S^- - S^+} \right) + (1 - \gamma) \left(\frac{R_m - R^+}{R^- - R^+} \right) \tag{15}$$

where

$$S^+ = \min_{m \in i} S_m \tag{16}$$

$$S^- = \max_{m \in i} S_m \tag{17}$$

$$R^+ = \min_{m \in i} R_m \tag{18}$$

$$R^- = \max_{m \in i} R_m \tag{19}$$

where the parameter γ represents the preference given to the strategy and usually it is taken as 0.5. Finally, arrange the alternatives in increasing order. The highest rank is selected as the optimal solution.

4.5 GRA (Grey Relational Analysis)

GRA is the part of the grey game theory, which is used for selection of alternatives having partial information. It solves the selection problem by taking the complete range of attributes value of every alternative into one, single value [36].

Step 1: For one scale transformation, normalization is done by using Eq. (4).

Step 2: After normalization, the parameters matrix is scaled into [0, 1]. If any of the elements is equal to, or nearer to one, it means the performance of corresponding alternatives is the best one for those parameters. But, this kind of alternatives does not always exist. Due to this, the reference sequence is defined by B_0 as

$$(b_{01}, b_{02}, \ldots \ldots b_{0n}) = (1, 1, \ldots \ldots 1) \tag{20}$$

The aim of the reference sequence is to find that alternatives whose compatibility is closest to the maximum value or reference sequence.

Step 3: Then, calculate the grey relational coefficient to determine how close normalized matrix b_{mn} is to b_{0n}. The larger the coefficient value, the closer b_{mn} and b_{0n} are. Grey relational coefficient is calculated by

$$\xi_{mn} = \frac{\underset{m}{min}\left(\underset{m}{min}\left|b_{0n} - b^*_{mn}\right|\right) + \rho^{max}_{m}\left(\underset{n}{max}\left|b_{0n} - b^*_{mn}\right|\right)}{\left(\left|b_{0n} - b^*_{mn}\right|\right) + \rho^{max}_{m}\left(\underset{n}{max}\left|b_{0n} - b^*_{mn}\right|\right)} \tag{21}$$

where ρ is the distinguishing coefficient, $\rho\epsilon[0, 1]$ and usually it is taken as 0.5.

Step 4: The score is calculated by multiplying the relational coefficient by the AHP weight.

$$S_{GRA} = \sum_{n=1}^{j} w_n \xi_{mn}. \tag{22}$$

5 Prospect Theory

Prospect theory is proposed by Kahneman and Tversky in 1979 [37]. It was used for decision making mostly in the field of economics [38] but in this paper, it is used for protocol selection. It is the part of grey game theory in which the risk attitude is considered. The selection is based on the gain and loss prospective and divided into two phases: editing and evaluation phase. The reference point is defined in the editing phase and value function and weight function is defined in the evaluation phase. The value function is defined by

$$e_{ij} = \begin{cases} x^{\alpha} & x \geq 0 \\ -\lambda\left(-x^{\beta}\right) & x < 0 \end{cases} \tag{23}$$

Where α and β are the parameters which define the concavity and convexity of the value function and λ is the loss aversion coefficient.

Another name given to the prospect theory is the “Risk MADM” because it is used for selection from multi attributes factors with a risk factor and there are some steps that are taken from the MADM method [39].

Step 1: First of all, the normalization is done by using Eq. (4).

Step 2: The positive and negative ideal solution is defined by Eq. (8) and (9) as in TOPSIS method.

Step 3: After that grey relational coefficient is calculated for both positive and negative ideal solution.

$$\xi_{mn}^{+} = \frac{\underset{m}{min}\left(\underset{n}{min}\left|a_{mn} - v_n^{+}\right|\right) + \rho \underset{m}{max}\left(\underset{n}{max}\left|a_{mn} - v_n^{+}\right|\right)}{\left(\left|a_{mn} - v_n^{+}\right|\right) + \rho \underset{m}{max}\left(\underset{n}{max}\left|a_{mn} - v_n^{+}\right|\right)} \tag{24}$$

$$\xi_{mn}^{-} = \frac{\underset{m}{min}\left(\underset{n}{min}\left|a_{mn} - v_n^{-}\right|\right) + \rho \underset{m}{max}\left(\underset{n}{max}\left|a_{mn} - v_n^{-}\right|\right)}{\left(\left|a_{mn} - v_n^{-}\right|\right) + \rho \underset{m}{max}\left(\underset{n}{max}\left|a_{mn} - v_n^{-}\right|\right)} \tag{25}$$

The grey relational coefficient is used to determine the closeness of compared sequence to the ideal solution. If the coefficient value is larger, then the two sequence is closer and vice versa.

Step 4: Then positive and negative prospect value function is defined by

$$v_{mn}^{+} = \left(1 - \xi_{mn}^{-}\right)^{0.88} \tag{26}$$

$$v_{mn}^{+} = -2.25\left[-\left(\xi_{mn}^{+} - 1\right)\right]^{0.88} \tag{27}$$

Step 5: After defining the prospect value function, prospect weight is calculated by

$$\pi^{+}\left(w_n\right) = \frac{w_n^{\gamma_n^{+}}}{\left[w_n^{\gamma_n^{+}} + \left(1 - w_n\right)^{\gamma_n^{+}}\right]^{1/\gamma_n^{+}}} \tag{28}$$

$$\pi^{-}\left(w_n\right) = \frac{w_n^{\gamma_n^{-}}}{\left[w_n^{\gamma_n^{-}} + \left(1 - w_n\right)^{\gamma_n^{-}}\right]^{1/\gamma_n^{-}}} \tag{29}$$

where γ is the weighting function parameter lies in the range of 0.60 to 0.71 for gain and 0.51 to .76 for loss. The author in the paper [40–42] tested the different values of weight function and finally, it is concluded that value of $\gamma_n^{+}=0.61$ and $\gamma_n^{-}=0.69$ is fitted properly in the selection process.

Step 6: Finally, by using the SAW method the prospect score is calculated by

$$V_m = \sum_{n=1}^{j} v_{mn}^{+}\pi^{+}\left(w_n\right) + v_{mn}^{-}\pi^{-}\left(w_n\right) \tag{30}$$

Then arrange the V_m in the descending order. The first alternative is selected as the optimal solution.

6 Performance Metric

The performance of ranking scores obtained by different methods is shown in terms of accuracy. The difference between the maximum and minimum ranking value of two protocols is corresponding to the accuracy of obtained ranking scores. As one protocol has maximum score while another protocol has the minimum score in the whole scale of ranking, then accuracy is calculated by the difference between maximum and minimum score value. When the difference between the two-ranking value is very small, then it is very difficult to identify which protocol is best. This situation may lead to confusion in the decision-making process. So, the difference between two ranking value should be larger so that it is easy to identify the best protocol. The difference between two ranking values of protocol allows determining the accuracy of the algorithm.

7 Result and Discussion

Several PMIPv6 schemes are proposed for reducing the handoff latency, packet loss, DAD operation. Handoff latency is actually the time gap between IP packets which is received from MAG1 and MAG2 i.e. at the time of handoff. Packet loss is the number of lost packets in MN at the time of handoff. The packet loss can be due to any reasons such as lost connection, butter overflow etc. At the time of handoff, MN configures its address and DAD once. But in some cases, it configures its DAD operation several times, which should be avoided. If DAD operation is performed several times, then time spent on DAD operation is increased which is not desirable. So, it should be configured only once. For reducing the handoff

Table 3 Different protocols ranking [24–32]

Protocol	Handoff latency	Packet loss rate	Spent time on DAD	Signaling cost
FH-PMIPv6	3	3	4	4
HF-PMIPv6	3	3–4	3	3–4
FL-PMIPv6	2	2–3	2–3	3–4
PL-PMIPv6	2	4	3	3–4
MN-HNP	3	3	3	4
PMIP-MHA	3	2–3	3	5
Smart buffering	2	2	3	4
Head MAG	2	2	3	5

latency, packet loss etc. additional overhead is provided during handoff but due to this, the signaling cost of handoff is increased.

For the evaluation, eight different mobility management protocols are considered. Every protocol has its own specification in terms of QoS parameters (handoff latency, packet loss rate, spent time on DAD procedure) and signaling cost. The ranking of different protocols in terms of QoS parameters and signaling cost is given in Table 3 where ranking 5 indicate the maximum value and ranking 1 indicates the minimum value. These ranking scores are obtained by reviewing the different papers. The simulation is performed on MATLAB software.

7.1 Weight Calculation results

AHP method is used for assigning the weights in which user preference is considered. For streaming traffic class, QoS parameters are taken as an important factor. The pairwise comparison matrix for streaming traffic class by applying the AHP method is represented in Table 4. The number 1,3,5,7 is allocated according to Saaty`s scale using Table 2. The parameters are placed according to the descending order of weights. Streaming traffic class is used for video application which requires a continuous flow of information so first preference is given to handoff latency and second preference is given to packet loss rate. Similarly, third preference is given to spent time on DAD and least preference is given to signaling cost. In the first row of the matrix, the handoff latency is compared to the all parameters, Firstly, the handoff latency is compared with itself i.e. with handoff latency, which is equally important so number 1 assigned from the Table 2. Next, the handoff latency is compared to the packet loss rate and handoff latency is moderately important than packet loss rate so number 3 is assigned from Table 2. Now, the comparison of handoff latency is done with DAD spent time and signaling cost. The handoff latency is strongly and very strongly important than DAD spent time and signaling cost respectively, so number 5 and 7 is assigned to the third and fourth column of the first row. In the second row, the packet loss rate is compared with the all parameters, firstly it is compared to the handoff latency. In this case, the packet loss rate is less important than latency, so it is assigned 1/3 as defined in step 2 of AHP. Next, it is compared with itself, and a number 1 is assigned to the second column in the second row. In the third and fourth column of the second row, the packet loss rate is compared to the DAD time and signaling cost. The packet loss rate is moderately important than DAD time and strongly important from the signaling cost and number 3 and 5 is assigned

Table 4 The pairwise comparison matrix for streaming traffic class

Parameter	Handoff latency	Packet loss rate	Spent time on DAD	Signaling cost
Handoff latency	1	3	5	7
Packet loss rate	1/3	1	3	5
Spent time on DAD	1/5	1/3	1	3
Signaling cost	1/7	1/5	1/3	1

Table 5 The pairwise comparison matrix for background traffic class

Parameter	Signaling cost	Packet loss rate	Handoff latency	Spent time on DAD
Signaling cost	1	3	5	7
Packet loss rate	1/3	1	3	5
Handoff latency	1/5	1/3	1	3
Spent time on DAD	1/7	1/5	1/3	1

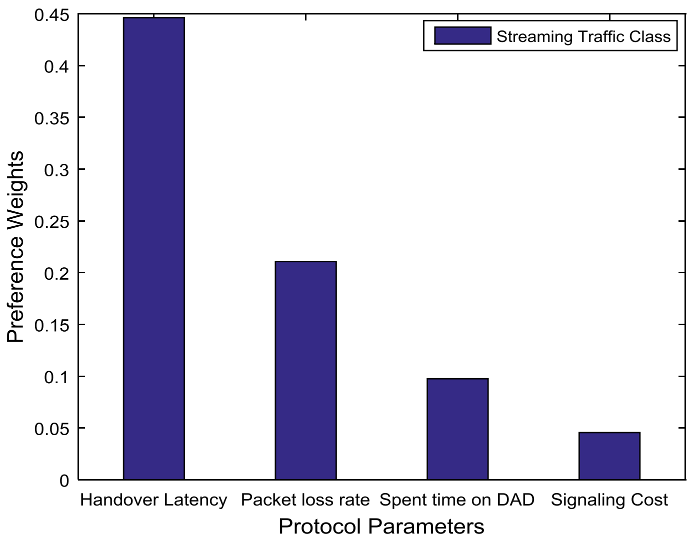

Fig. 2 Weight of different protocols for streaming traffic class

respectively from the Saaty's scale. Similarly, the third and fourth row is generated by comparing the DAD time and signaling cost with all parameters. The pairwise comparison matrix for background traffic class is shown in Table 5 in which the first preference is given to the signaling cost, second preference is given to packet loss rate and third and fourth preference is given to the handoff latency and DAD time respectively. The matrix is constructed same as the Table 4 but the preferences are different. After constructing the pairwise matrix, the weight is calculated by applying the Eqs. (1) and (2) of AHP method. The calculated weight for streaming and background traffic class is shown in Figs. 2 and 3. In Fig. 2, the maximum weight is assigned to the handoff latency because we give most preference to that parameter. For background traffic class, signaling cost is given most preference as shown in Fig. 3. Background traffic class is used for emails and telemetry application in which QoS parameter doesn't matter but the only cost should be minimum. The protocol is selected based on the AHP weight calculation. The reason for using AHP method is to increase the QoE of the user because in this case user can give preference according to their application and requirement.

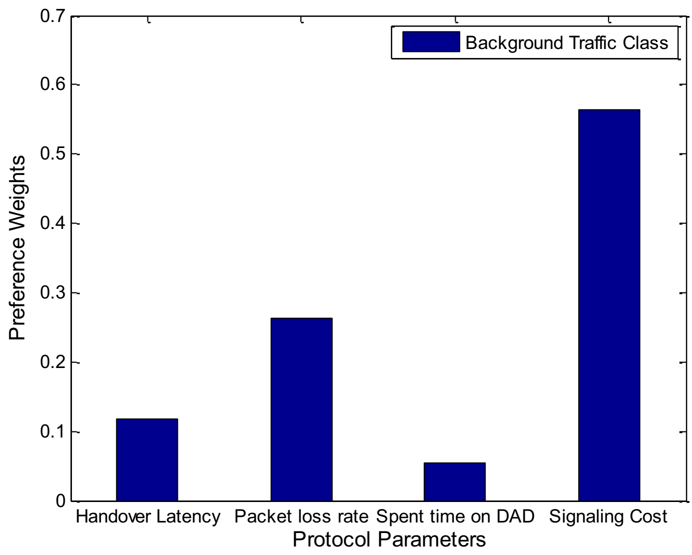

Fig. 3 Weight of different protocols for background traffic class

Fig. 4 Protocol scores for different application using SAW method

7.2 Score Calculation Results

In this paper, protocol selection problem is simulated by the MADM method and prospect theory. The performance of these methods is shown in terms of different application.

Fig. 5 Protocol scores for different application using MEW method

The protocol selected by SAW and MEW method is shown in Figs. 4 and 5 respectively. As shown in weight calculation results, for streaming application, the maximum weight is given to handoff latency, packet loss rate and spent time on DAD procedure respectively, so smart buffering PMIPv6 protocol is selected. As shown in Table 3, smart buffering PMIPv6 protocol and head MAG PMIPv6 protocol has minimum value of handoff latency, packet loss rate and spent time on handoff procedure but the cost of head MAG protocol has the highest signaling cost. As these two protocol has the same range of first three preferences, so in this case, fourth preference is considered and smart buffering protocol is selected for streaming application. As shown in Table 3, the smart buffering protocol has least value of handoff latency, packet loss rate, spent time on DAD procedure, so it is selected every time and it is suitable for the next-generation wireless network. But it has larger signaling cost, so it is not selected for background traffic class. As background application gives most preference to cost parameters, so FL-PMIPv6 protocol is selected. Although, various protocols such as HF-PMIPv6, FL-PMIPv6, PL-PMIPv6 provide minimum cost then in this case after first preference, second and third preferences are considered. As shown in Fig. 3, the second preference is given to packet loss rate and third preference is given to handoff latency so the protocol which has a minimum value of those parameters is selected. HF-PMIPv6 protocol has larger packet loss rate and larger handoff latency, PL-PMIPv6 has larger packet loss rate and smaller handoff latency and FL-PMIPv6 has smaller packet loss rate and handoff latency, so FL-PMIPv6 protocol is selected for background application. SAW method is easy to implement and it can accommodate multiple criteria for selection with less complexity. MEW method is the least sensitive method and its complexity is somewhat greater than SAW method but fewer complexes than another method.

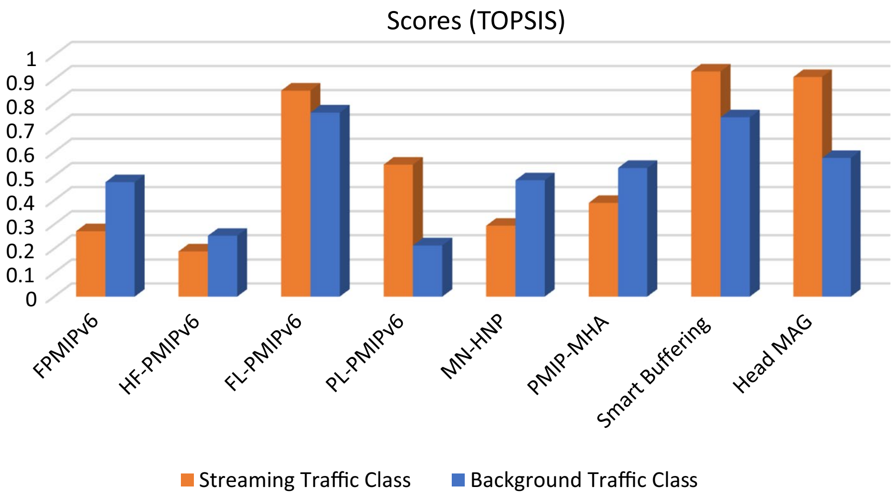

Fig. 6 Protocol scores for different application using TOPSIS method

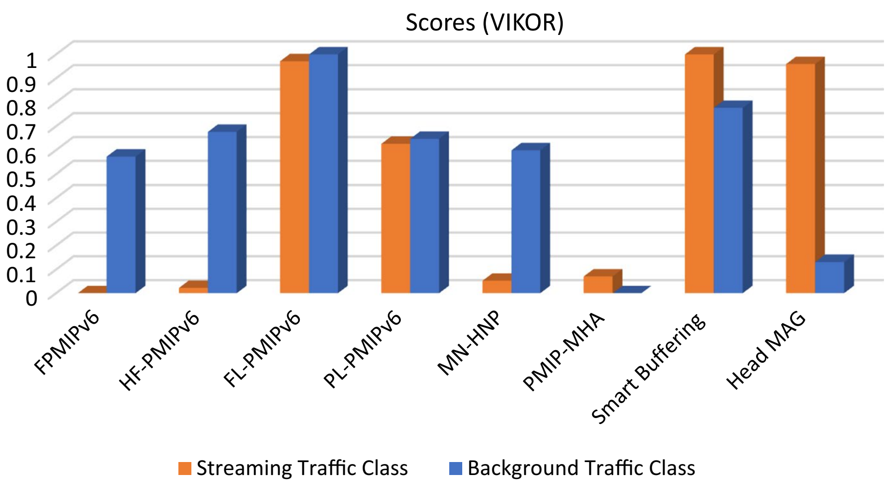

Fig. 7 Protocol scores for different application using VIKOR method

The scores of different protocols calculated by TOPSIS, VIKOR and GRA method is shown in Figs. 6, 7 and 8 respectively. For streaming application, highest weight is given to handoff latency, so the smart buffering protocol is selected for the same reason. As smart buffering protocol provides best QoS, so it is suitable for high mobility applications. For background application, due to maximum weight of cost parameter, the FL-PMIPv6 protocol is selected because it provides minimum value of signaling cost. The concept of TOPSIS method is simple and comprehensive. It gives an accurate result with high efficiency and flexibility. Among all

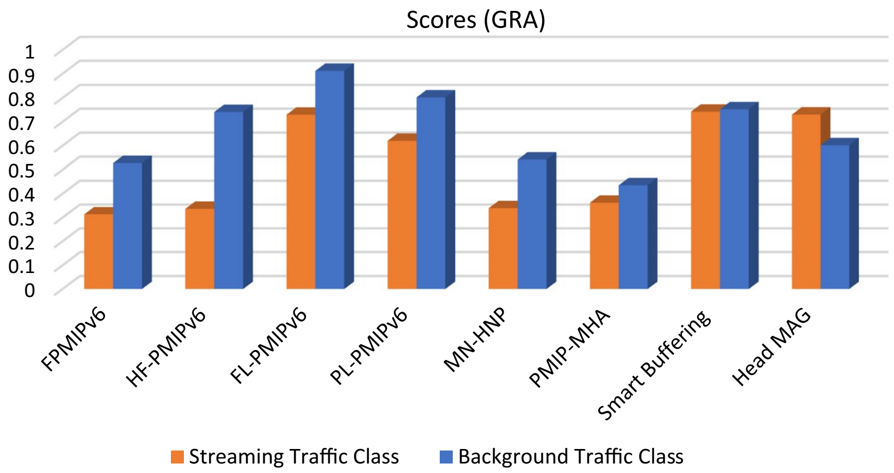

Fig. 8 Protocol scores for different application using GRA method

MADM method, the accuracy of VIKOR method is largest. GRA method can handle many parameters and give a precise solution. But it is very complicated because as the number of level increases, length of the process also increases.

In MADM algorithm, selection is done on the basis of user's preferences and user always tries to maximize their utility so their decision may lead to inefficient performance. However, MADM methods e.g. TOPSIS and GRA are known to suffer from ranking abnormalities, which may result in the ranking variation of alternatives/protocols when an alternative is added or removed. The problem of

Fig. 9 Protocol scores for different application using prospect theory

ranking abnormalities occurs due to removing of low ranking alternative from the candidate list and then ranking order is changed. An efficient MADM algorithm requires that the best alternative does not change due to removing or replacing a low rank alternative. Therefore, if any algorithm is suffering from this problem, then the ranking order is not stable.

For removing the drawback of MADM application, prospect theory is used. The protocol scores obtained by prospect theory are shown in Fig. 9. In the prospect theory, the maximum score is given to smart buffering for streaming application because it has best QoS parameter same as in the MADM method. Smart buffering PMIPv6 protocol and head MAG PMIPv6 protocol both has best QoS parameter but signaling cost is larger for head PMIPv6 protocol. So, by considering of all preference, the smart buffering protocol is selected. For background traffic class, FL-PMIPv6 is selected due to least signaling cost parameter although HF-PMIPv6, FL-PMIPv6, PL-PMIPv6 protocols provide minimum cost but HF-PMIPv6 protocol has larger packet loss rate and larger handoff latency, PL-PMIPv6 has larger packet loss rate and smaller handoff latency and FL-PMIPv6 has smaller packet loss rate and handoff latency, so FL-PMIPv6 protocol is selected for background application. The all user preference (not only highest preference/weight) is considered in the prospect theory. The advantage of prospect theory is that it is simple. The prospect theory is also used for risk calculation in case of unknown parameter weight [43]. In that case objective method is used for determining the weight according to the deviation of parameters range and then prospect theory is used for score calculation and risk of wrong protocol selection.

7.3 Accuracy of Different Score Calculation Results

The accuracy is calculated for different ranking scores obtained by different methods in the last section. The accuracy of different ranking scores obtained by different methods is shown in Table 6. The difference between maximum ranking and minimum ranking values of alternatives determine the accuracy of the algorithm. As shown in Table 6, prospect theory has maximum accuracy. In the MADM algorithm, VIKOR gives the more accurate result. In comparison of MADM algorithm and prospect theory, prospect theory gives most accurate result for all applications. The prospect theory is 66% more accurate as compared to the MADM algorithm for streaming application and 70% is more accurate for background application. So in terms of accuracy, prospect theory gives the best selection results.

Table 6 Accuracy of ranking scores

Protocol	SAW	MEW	TOPSIS	VIKOR	GRA	Prospect theory
Streaming	0.2393	0.2490	0.743	1.000	0.4289	1.5695
Background	0.2176	0.2151	0.549	1.000	0.4764	1.6643

8 Conclusion

Mobility management protocols are necessary for providing the seamless handoff to end user regardless of their location. IETF has developed the different protocols for the next-generation wireless network. In this paper, a brief introduction of different protocols based on PMIPv6 protocol is given. Then the best protocol is selected for specific applications based on QoS and signaling cost parameters. Two applications have been considered i.e. streaming and background application. For streaming application; QoS parameters are more important so highest weight is given to QoS parameters (handoff latency) and for background traffic class; the cost is more important, so, the highest weight is given to signaling cost. AHP method is used for assigning the weight for different applications that enhance the QoE of the user in the selection process. Then MADM and prospect theory have been used for selection of protocols. The simulation results show that smart buffering PMIPv6 protocol is selected for streaming application due to finest QoS parameters i.e. minimum value of handoff latency, packet loss rate, and spent time on DAD. Although smart buffering PMIPv6 protocol has larger signaling cost, but, cost doesn't matter here. So, the smart buffering PMIPv6 protocol is suitable for those applications where QoS is more important. For background application, the cost is more important so more weight is given to cost parameter and in this application also MADM and prospect theory both select FL-PMIPv6 protocol as the best protocol. The results are verified in terms of accuracy. Results show that prospect theory provides 66–70% more accurate results as compared to MADM algorithm. Here two selection methods have been used for validation of result. So, for next-generation mobile communication, smart buffering PMIPv6, and FL-PMIPv6 protocols are recommended for applications where QoS and cost respectively are more important respectively.

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