DNS: Dynamic Network Selection Scheme for Vertical Handover in Heterogeneous Wireless Networks

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ABSTRACT
Seamless Service delivery in a heterogeneous wireless network environment demands selection of an optimal access network. Selecting a non-promising network, results in higher costs and poor services. In heterogeneous networks, network selection schemes are indispensable to ensure Quality of Service (QoS). The factors that have impact on network selection include Throughput, Delay, Jitter, Cost and Signal Strength. In this paper, multi-criteria analysis is done to select the access network. The proposed scheme involves two schemes. In the first scheme, Dynamic Analytic Hierarchy Process (AHP) is applied to dynamically decide the relative weights of the evaluative criteria set based on the user preferences and service applications. The second scheme adopts Modified Grey Relational Analysis (MGRA) to rank the network alternatives with faster and simpler implementation. The proposed system yields better results in terms of Throughput, delay and Packet Loss Ratio (PLR).

Keywords
Multi-Criteria Decision Making (MCDM) Scheme, Analytic Hierarchy Process (AHP), Grey Relational Analysis (GRA), WiMAX, WiFi, QoS.

1. INTRODUCTION
Rapid development of multimedia applications in the wireless environment has led to the development of many broadband wireless technologies. IEEE 802.16, a standard proposed by IEEE for Worldwide Interoperability for Microwave Access (WiMAX) suggests modifications to the Medium Access Control (MAC) and Physical (PHY) layers to efficiently handle high bandwidth applications. IEEE 802.16 standards ensure Quality of Service

(QoS) for different types of applications supporting different types of service classes[1].

1.1 IEEE 802.16 - WiMAX

IEEE 802.16, a solution to Broadband Wireless Access (BWA) is a wireless broadband standard that promises high bandwidth over long range of coverage[2]. The IEEE 802.16-2001 standard specified a frequency range from 10 to 66 GHz with a theoretical maximum bandwidth of 120 Mbps and a maximum transmission range of 50 kms. The initial standard supported only the Line-Of-Sight (LOS) transmission and did not favor deployment in urban areas.

IEEE 802.16a-2003 supports Non-LOS (NLOS) transmission and supports a frequency range of 2 to11 GHz. IEEE 802.16 standard underwent several amendments and evolved to the 802.16-2004standard (also known as 802.16d). It provided technical specifications to the PHY and MAC layers for fixed wireless access and addresses the first or last mile connection in Wireless Metropolitan Area Networks (WMANs).

IEEE 802.16e added mobility support. This is generally referred to as mobile WiMAX and adds significant enhancements as listed below.

- ✓ It improves the NLOS coverage using advanced antenna diversity schemes and Hybrid Automatic Repeat Request (HARQ).
- ✓ It adopts dense Subchannelization, thus increasing system gain and improving indoor penetration.
- ✓ It uses Adaptive Antenna System (AAS) and Multiple Input Multiple Output (MIMO) technologies to improve coverage.
- ✓ It introduces a DL Subchannelization scheme enabling better coverage and capacity trade-off. This brings potential benefits in terms of coverage, power consumption, self-installation and frequency reuse and bandwidth efficiency.

With the rising popularity of multimedia applications in the Internet, IEEE 802.16 provides the capability to offer new wireless services such as multimedia streaming, real-time surveillance, Voice over IP (VoIP) and multimedia conferencing. Due to its long range and high bandwidth transmission, IEEE 802.16 is also considered in areas where it can serve as the backbone network with long separation among the infrastructure nodes. Cellular technology using VoIP over WiMAX is another promising area.

WiMAX supports different types of traffics like Unsolicited Grant Service (UGS), rtPS (real-time Polling Service), ertPS (extended real-time Polling Service), nrtPS (non-real-time Polling Service) and Best Effort (BE).

Unsolicited Grant Service (UGS): Specifically designed for Constant Bit Rate (CBR) services such as T1/E1 emulation and VoIP without silence suppression.

Extended Real-Time Polling Service (ertPS): Built on the efficiency of both the UGS and rtPS. This is suitable for applications such as VoIP with silence suppression.

Real-Time Polling Service (rtPS): Designed for real-time services that generate variable size data packets on periodic basis such as MPEG video.

Non-Real-Time Polling Service (nrtPS): Designed for delay tolerant services that generate variable size data packets on a regular basis.

Best Effort (BE) Service: Designed for applications without any QoS requirements such as HTTP service.

One of the main challenges in QoS provisioning is the effective mapping of the QoS requirements of potential applications across different wireless platforms [3].

1.1.1 Physical Layer

Orthogonal Frequency Division Multiplexing (OFDM) in the PHY layer enables multiple accesses by assigning a subset of Subcarriers to users. This resembles Code Division Multiple Access (CDMA) spread spectrum that provides different QoS to each user. OFDM is achieved by multiplexing on the user’s data streams on both Uplink (UL) and Downlink (DL) transmissions. The IEEE 802.16e Standard specifies the OFDMA based PHY layer that has distinct features like flexible Subchannelization, Adaptive Modulation and Coding (AMC), Space-time coding, Spatial multiplexing, Dynamic Packet Switch based air interface and flexible network deployment such as Fractional frequency reuse [7]. AMC employed in the PHY layer dynamically adapts the modulation and coding scheme to the channel conditions so as to achieve the highest spectral efficiency at all times [8].

1.1.2 MAC Layer

The 802.16 MAC is designed to support a Point-to-Multipoint (PMP) architecture with a central Base Station (BS) communicating simultaneously with multiple Mobile Subscriber Stations (MSSs). The MAC includes the following Sublayers namely:

Service Specific Convergence Sublayer (CS)- It maps the service data units to the appropriate MAC connections, preserves or enables QoS and bandwidth allocation.

Common Part Sublayer (CPS)- It provides a mechanism for requesting bandwidth, associating QoS and traffic parameters, transporting and routing data to the appropriate convergence Sublayer.

Privacy Sublayer - It provides authentication of network access and assists in connection establishment [9].

1.2 IEEE 802.11 - WiFi

WLAN (or WiFi) is an open-standard technology that enables wireless connectivity between equipments and Local Area Networks (LANs). Public access WLAN services are designed to deliver LAN services over short distances. Coverage extends over a 50 to 150 meter radius of the Access Point (AP). Connection speeds range from 1.6 Mbps to 11 Mbps which is comparable to fixed Digital Subscriber Line (DSL) transmission speed [4].New standards promise to increase speeds upto 54 Mbps. Today's WLANs run in the unlicensed 2.4 GHz and 5 GHz radio spectrums [5]. The 2.4 GHz frequency is already jam-packed - it is used for several purposes besides WLAN service. The 5 GHz spectrum is a much larger bandwidth providing higher speeds, greater reliability, and better throughput [6].

1.3 HANDOVER

Handover is the process of transferring an ongoing call or data session from one channel connected to the core network to another. The WiMAX technology specifies a variety of handover schemes to transfer a call or data from the control of one network to another. When a MSS moves from one BS to another, the control information is transferred from the BS to which the MSS is currently linked referred to as the home Base Station (hBS) to the BS under the range of which the MSS is to be connected referred to as target Base Station (tBS).

Handover is of two types based on the technology of the networks involved namely, Horizontal Handover and Vertical Handover. Figure. 1 illustrates the WiMAX - WiFi network architecture where the MSS is handed over to the optimal nearby BS or AP. The handovers based on access networks include:

Horizontal Handover-The mobile user switches between networks with the same technology.

Vertical Handover (VHO) -The users switch among networks with different technologies, for example, between an IEEE 802.11 AP and a cellular network BS. In heterogeneous networks, VHO is mainly used. Users can move between different access networks. They benefit from different network characteristics (coverage, bandwidth, frequency of operation, data rate, latency, power consumption, cost, etc.) that cannot be compared directly [10].

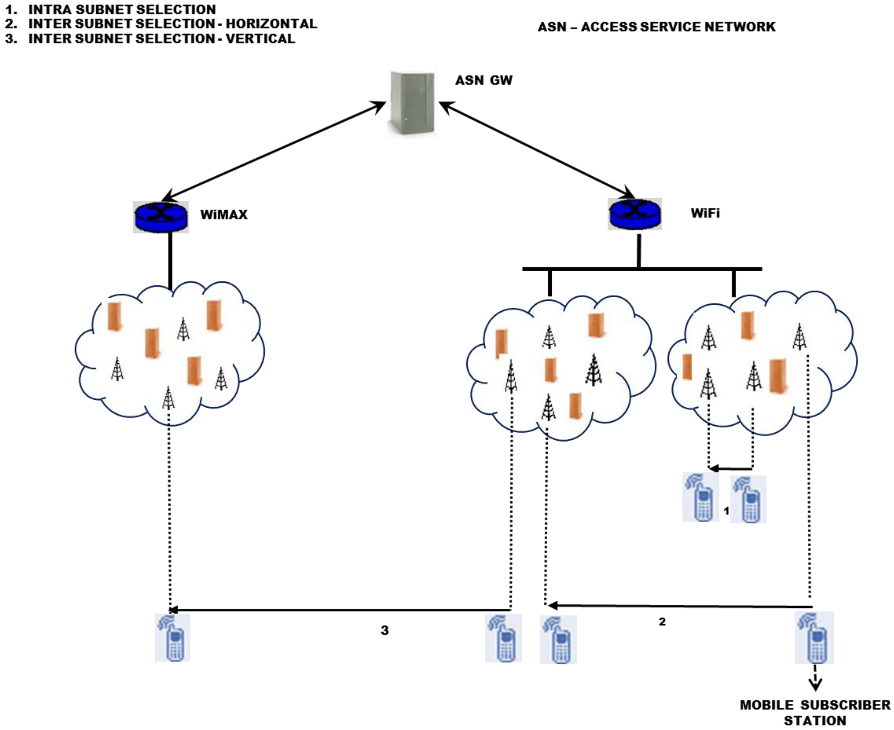

Figure 1. WiMAX - WiFi Network Architecture

2. RELATED WORK

A link reward function and a signaling cost function are presented in [11] to capture the tradeoff between the network resources utilized by the connection and the signaling and processing load acquired on the network. A stationary deterministic policy is obtained when the connection termination time is geometrically distributed.

A novel optimization utility is presented in [12] to assimilate the QoS dynamics of the available networks along with heterogeneous attributes of each user. The joint network and user selection is modelled by an evolutionary game theoretical approach and replicator dynamics is figured out to pursue an optimal stable solution by combining both self-control of users' preferences and self-adjustment of networks' parameters.

A survey on fundamental aspects of network selection process is discussed in [13]. It deals with network selection to the always best connected and served paradigm in heterogeneous wireless environment as a perspective approach.

A mechanism [14] based on a unique decision process that uses compensatory and non-compensatory multi-attribute decision making algorithms is proposed, which jointly assists the terminal in selecting the top candidate network.

A cross layer architectural framework for network and channel selection in a Heterogeneous Cognitive Wireless Network (HCWN) is proposed in [15]. A novel probabilistic model for channel classification based on its adjacent channels' occupancy within the spectrum of an operating network is also introduced. Further, a modified Hungarian algorithm is implemented for channel and network selection among secondary users.

In [16], a Satisfaction Degree Function (SDF) is proposed to evaluate the available networks and find the one that can satisfy the mobile user. This function not only considers the specific network conditions (e.g. bandwidth) but also the user defined policies and dynamic requirements of active applications.

In [17], a two-step vertical handoff decision algorithm based on dynamic weight compensation is proposed. It adopts a filtering mechanism to reduce the system cost. It improves the conventional algorithm by dynamic weight compensation and consistency adjustment.

A speed-adaptive system discovery scheme suggested in [18] for execution before vertical handoff decision improves the update rate of the candidate network set. A vertical handoff decision algorithm based on fuzzy logic with a pre-handoff decision method which reduces unnecessary handoffs, balancing the whole network resources and decreasing the probability of call blocking and dropping is also added.

In [19], the authors present a multi-criteria vertical handoff decision algorithm for heterogeneous wireless networks based on fuzzy extension of TOPSIS. It is used to prioritize all the available networks within the coverage of the mobile user. It achieves seamless mobility while maximizing end-users' satisfaction.

A network selection mechanism based on two Multi Attribute Decision Making (MADM) methods namely Multiple - Analytic Hierarchy Process (M-AHP) and Grey Relational Analysis (GRA) method is proposed in [20]. M-AHP is used to weigh each criterion and GRA is used to rank the alternatives.

A context-aware service adaptation mechanism is presented for ubiquitous network which relies on user-to-object, space-time interaction patterns which helps to perform service adaptation [21]. Similar Users based Service Adaptation algorithm (SUSA) is proposed which combines both Entropy theory and Fuzzy AHP algorithm (FAHP).

Load balancing algorithm based on AHP proposed in [22] helps the heterogeneous WLAN/UMTS network to provide better service to high priority users without decreasing system revenue.

3. CROSS LAYER DESIGN

To ensure seamless QoS, a Cross-Layered Framework is designed for network selection in heterogeneous environments. The PHY layer, MAC (L2) layer and the Network layer ((L3) are involved. The layers are closely coupled together (Figure 2).

TIER-1: It includes the PHY and the MAC layers. Resource availability is determined from the MAC layer. The parameters RSSI and SINR are taken from the PHY layer.
TIER-2: In the Network layer, network is selected for a MSS based on the factors determined from TIER-1.

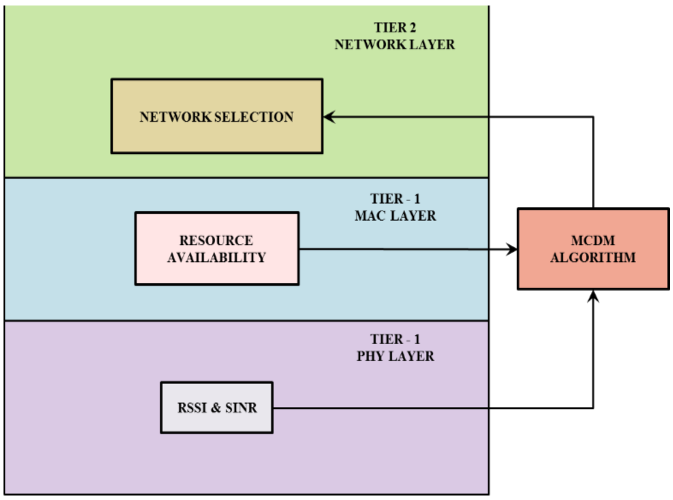

Figure 2. Cross Layer Design

4. MULTI- CRITERIA DECISION MAKING (MCDM) SHEMES

Handover decision problem deals with selecting network from candidate networks of various service providers involving technologies with different criteria. Network selection schemes can be categorized into two types - Fuzzy Logic based schemes and Multiple Criteria Decision Making (MCDM) based schemes.

Three different approaches for optimal access network selection are [23, 24]:

Network Centric - In network centric approach, the choice for access network selection is made at the network side with the goal of improving network operator's benefit. Majority of network centric approaches use game theory for network selection.
User Centric - In this approach, the decision is taken at the user terminal based only on the minimization of the user's cost without considering the network load or other users. The selection of the access network is determined by using utility, cost or profit functions

or by applying MCDM methods. The selection of an access network depends on several parameters with different relative importance such as network and application characteristics, user preferences, service and cost.

Collaborative Approaches - In the collaborative approach, selection of access network takes into account the profits of both the users and the network operator. It mainly deals with the problem of selecting a network from a set of alternatives which are categorized in terms of their attributes.

The two processes in MCDM techniques are weighting and ranking. Most popular classical algorithms include Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP) and Grey Relational Analysis (GRA).

- ✓ In Simple Additive Weighting (SAW), the overall score of a candidate network is determined by the weighting sum of all the attribute values.
- ✓ In Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), the chosen candidate network is one which is closest to the ideal solution and farthest from the worst case solution.
- ✓ Analytical Hierarchy Process (AHP) decomposes the network selection problem into several subproblems and assigns a weight for each subproblem.
- ✓ Grey Relational Analysis (GRA) ranks the candidate networks and selects the one with the highest ranking.

5. ANALYTIC HIERARCHY PROCESS (AHP)

AHP was introduced by Saaty [25] with the goal of making decisions about complex problems by dividing them into a hierarchy of decision factors which are simple and easy to analyze.

- ✓ AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion.
- ✓ Next, for a fixed criterion, it assigns a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion. The higher the score, the better the performance of the option with respect to the considered criterion.
- ✓ Finally, the AHP combines the criteria weights and the options scores thus determining a global score for each option and a consequent ranking. The global score for a given option is the weighted sum of the scores obtained with respect to all the criteria.

6. DYNAMIC ANALYTIC HIERARCHY PROCESS (DAHP)

In the proposed Dynamic AHP (DAHP), the weight of each criterion is assigned dynamically based on the Received Signal Strength Indicator

(RSSI) and Signal to Noise Interference Ratio (SINR) values of a MSS with respect to a BS or AP. A network with high RSSI and low SINR is given priority. Likewise, the values of both RSSI and SINR are calculated at regular intervals and the weights are assigned. Table 1 shows the possible weights that are assigned to a network based on the parameter values.

Table 1: Weights Assignment based on values

RESOURCE AVAILABILITY	RSSI	SINR	SELECT/REJECT
AVAILABLE	High	High	Select (Worst Case)
	High	Medium	Select
	High	Low	Select
	Medium	High	Reject
	Medium	Medium	Select
	Medium	Low	Select
	Low	High	Reject
	Low	Medium	Reject
	Low	Low	Reject

DAHP involves the following steps:

Step 1: Determination of the objective and the decision factors: In this step, the final objective of the problem is analyzed based on a number of decision factors. They are further analyzed until the problem acquires a hierarchical structure. In the lowest level, the alternative solutions of the problem are found (Figure 3).

Step 2: Determination of the relative importance of the decision factors with respect to the objective: In each level, decision factors are pairwise compared according to their levels of influence with respect to the scale in Table 1. If there are 'n' decision factors, then the total number of comparisons will be 'n (n - 1)/2'. For qualitative data such as preference, ranking and subjective opinions, it is suggested to use a scale from 1 to 7 as shown in Table 2.

Table 2: Scale of Importance

PREFERENCE LEVELS	VALUES
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7

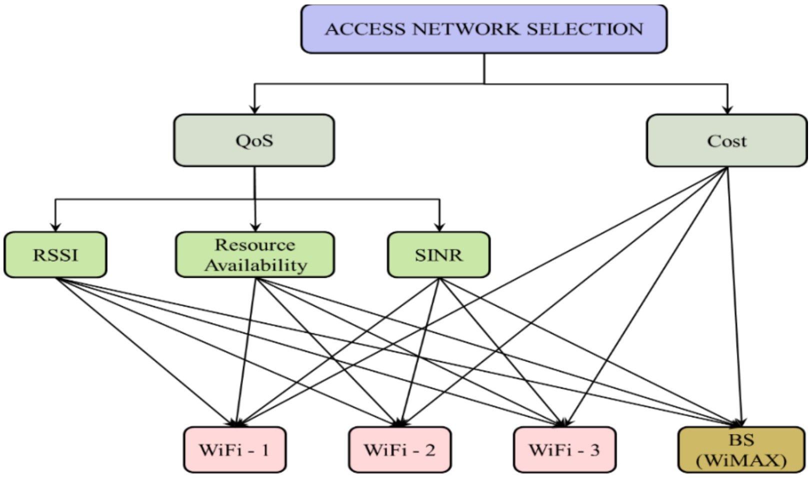

Figure 3. Hierarchy of criteria and alternatives

Initially, a pair-wise comparison 'n×n' matrix 'A[i][j]' is formed, where 'n' is the number of evaluation criterion considered. Each entry 'a_{ij}' of the matrix represents the importance of the criterion relative to the 'j^{th}' criterion.

If a_{ij}=1, an element is compared with itself.
If a_{ij}>1,then element 'i' is considered to be more important than element 'j'.
If a_{ij}<1,then element 'j' is considered to be more important than element 'i'.
$a_{ij} = \frac{1}{a_{ji}}$for the rest of the values of the table.

Each entry is multiplied with the respective parameter values which increases the accuracy of the criterion weights.

The entries 'a_{jk}' and 'a_{kj}' satisfies the following constraint:

$$a_{jk} * a_{kj} = 1 \quad (1)$$

Also,$a_{jj} = 1$ for all 'j'.

Step3: Normalization and calculation of the relative weights: Relative weight is a ratio scale that can be divided among decision factors. The relative weights are calculated by following the steps given below.

- ✓ Each column of matrix A is summed.
- ✓ Each element of the matrix is divided by the sum of its column. The relative weights are normalized. After normalizing, the sum of each column is one.

- ✓ Normalized principle Eigen vector is obtained by finding the average of rows after normalizing.
- ✓ A priority vector is obtained which shows the relative weights among decision factors that are compared. Normalized principle Eigen vector gives the relative ranking of the criteria used.
- ✓ For consistency, largest Eigen value (λ_{max}) is obtained from the summation product of each element of the Eigen vector and sum of columns of matrix A.

$$A = \begin{matrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{matrix} \xrightarrow[\text{Column Sums}]{\text{Normalized}} \begin{matrix} 0.30 & 0.29 & 0.38 \\ 0.60 & 0.57 & 0.50 \\ 0.10 & 0.14 & 0.13 \end{matrix} \xrightarrow{\text{Row Averages}} X = \begin{matrix} 0.30 \\ 0.60 \\ 0.10 \end{matrix}$$

When many pairwise comparisons are performed, some inconsistencies typically arise. AHP incorporates an effective technique for checking the consistency of the evaluations made by the decision maker when building each pairwise comparison matrix involved in the process and it mainly depends on the computation of a suitable Consistency Index (CI). The CI is obtained by computing the scalar ‘x’ as the average of the elements of the vector whose ‘j^{th}’ element is the ratio of the ‘j^{th}’ element of the vector ‘A*w’ to the corresponding element of the vector ‘w’.

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{2}$$

A perfectly consistent decision maker should always yield CI=0. Small values of inconsistency may be tolerated. RI is the Random Index, i.e. the CI when the entries of ‘A’ are completely random. The values of RI for small problems ($m \leq 10$) are shown in Table 3.

Table 3: Values for Random Index

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In particular, if $\frac{CI}{RI} \leq 10\%$, the inconsistency is acceptable and a reliable result may be expected. If the consistency ratio is greater than 10%, pairwise comparison should be initiated from the beginning.

7. MODIFIED GREY RELATIONAL ANALYSIS (MGRA)

Grey system theory is one of the methods used to study uncertainty and is considered superior in the mathematical analysis of systems with uncertain information. A system with partial information is called a grey system. GRA is a part of grey system theory which is suitable for solving problems with complicated interrelationships between multiple factors and variables. GRA method is widely used to solve the uncertainty problems with discrete data and incomplete information. One of the sequences is defined as reference sequence presenting the ideal solution. The grey relationship between the reference sequence and other sequences can be determined by calculating the Grey Relational Coefficient (GRC). MGRA involves the following steps.

Step 1: Classifying the series of elements into three categories: larger-the-better, smaller-the-better and nominal-the-best.
Step 2: Defining the lower, moderate or upper bounds of series elements and normalizing the entities.
Step 3: Calculating the GRCs.

Step 4: Selecting the alternative with the largest GRC.

The upper bound (u_j) is defined as

$$\max\{S_1(j), S_2(j), \ldots, S_n(j)\} \qquad (3)$$

and the lower bound (l_j) is calculated as

$$\min\{S_1(j), S_2(j), \ldots, S_n(j)\},(4)$$

For the moderate bound (m_j), the objective value between the lower and upper bound is considered.

- ✓ The absolute difference between '$S_i(j)$' and 'l_j' or 'u_j' divided by the difference between 'l_j' and 'u_j' achieves the normalization '$S_i^*(j)$' for larger or smaller, where i = 1… n.
- ✓ The normalization for nominal-the-best is presented as 'u_j' for larger-the-better, 'l_j' for smaller-the-better and 'm_j' for nominal-the-best. They are chosen to form a reference series 'S_0' which actually presents the ideal situation.

The GRC is computed from

$$\mathrm{GRC}_i = \frac{1}{\left[\left(\sum_{j=1}^{k} w_j \left|S_i^*(j) - 1\right|\right) + 1\right]} \qquad (5)$$

where w_j is the Weight of each parameter.

The comparative series with the largest GRC is given the highest priority.

8. RESULTS AND DISCUSSION

A heterogeneous network scenario is simulated using ns2. The simulation parameters are shown in Table4.Three different types of SLAs namely SLA1 (High), SLA2 (Medium) and SLA3 (Low) are considered.

- ✓ The most important selection criterion for SLA1 is the QoS satisfaction degree and not the cost of service.
- ✓ On the other hand, Cost criterion is more important than the degree of perceived QoS for SLA2 and SLA3.

When a Service Provider does not have resources or the QoS is not good, the users are moved to a WiFi network to improve the performance.

Table 4: Simulation Parameters

PARAMETER	VALUE
MAC	Mac/802.16e & 802.11
Packet Size	5000
Bandwidth	1 Mbps
Queue Length	50
Routing	DSDV
Simulation time	50 Sec

The Throughput (Figure 4)of the proposed DAHP is better when compared to the existing scheme. The proposed scheme offers 1.15, 1.11 and 1.05 times more Throughput when compared to AHP for SLA1, SLA2 and SLA3 respectively.

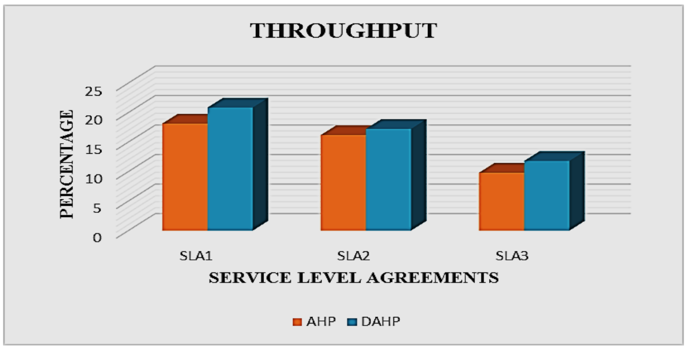

Figure 4. Throughput

The proposed scheme offers 1.03, 1.2 and 1.1 times less cost when compared to AHP for SLA1, SLA2 and SLA3 respectively (Figure 5).

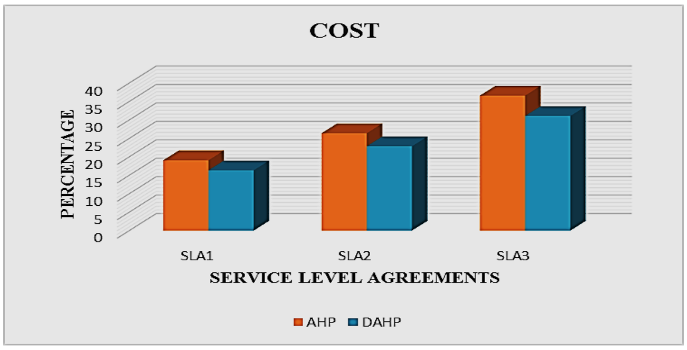

Figure 5. Cost

The Average Delay (Figure 6) of the AHP scheme is 1.46, 1.38 and 1.2 times more than that of DAHP.

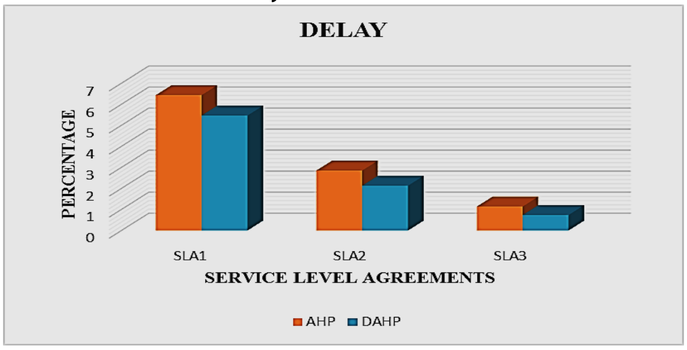

Figure 6. Delay

The proposed scheme offers 1.26, 1.19 and 1.24 times less Average Jitter when compared to AHP for SLA1, SLA2 and SLA3 respectively (Figure 7).

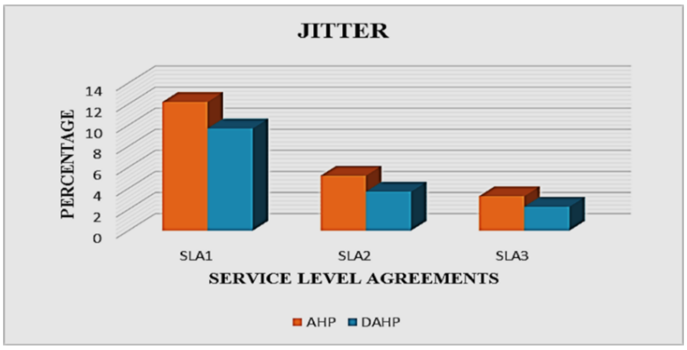

Figure 7. Jitter

Similarly, the Packet Loss Ratio (PLR) of DAHP is less when compared to former scheme as network selection is done dynamically based on the QoS values (Figure 8). The PLR of AHP scheme is 1.21, 1.12 and 1.13 times more than that of DAHP.

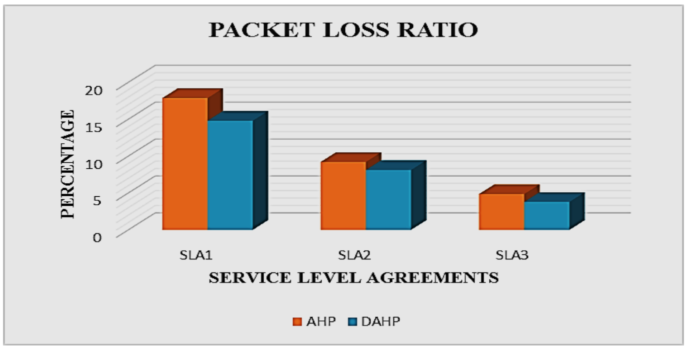

Figure 8. Packet Loss Ratio

9. CONCLUSION

An optimal network selection scheme is proposed for heterogeneous networks. The physical layer parameters such as Signal Strength and Noise

Ratio are integrated. This scheme dynamically weighs every possible candidate network for MSSs using DAHP and each is ranked by the MGRA. The proposed network selection algorithm provides seamless connection for the users over the heterogeneous network and enables the MSSs to forward the calls to the optimal network without dropping it. The simulation results reveal that the proposed network selection scheme efficiently decides the trade-off among user preference and network condition. It offers better Throughput involving less Cost, Delay, Jitter and PLR. In the future, the proposed scheme can be enhanced to include more network alternatives and selection criteria.

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