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AN INTELLIGENT VERTICAL HANDOVER DECISION ALGORITHM FOR WIRELESS HETEROGENEOUS NETWORKS

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ABSTRACT

The Next Generation Wireless Networks (NGWN) should be compatible with other communication technologies to offer the best connectivity to the mobile terminal which can access any IP based services at any time from any network without the knowledge of its user. It requires an intelligent vertical handover decision making algorithm to migrate between technologies that enable seamless mobility, always best connection and minimal terminal power consumption. Currently existing decision engines are simple, proprietary and its handover is only based on the received signal strength which has been proven unintelligent. The proposed decision algorithm gains intelligence by combining fuzzy logic system to handle imprecise data, multiple attribute decision making to handle multiple attributes for decision making and context aware strategies to reduce unnecessary handover. The proposed intelligent decision algorithm detects new network which offers best connectivity than current network and does authentication and mobile IP registration before making the handover; thereby reducing the packet loss to ensure high quality of service. This algorithm is capable of forwarding data packets to appropriate attachment point to maximize battery lifetime and also to maintain load balancing. The performance analysis shows that the proposed algorithm efficiently uses the network resources by switching between 3G and Wi-Fi under the different RF environmental conditions to offer best connectivity with minimal service cost to the users. It is observed that average handover delay for the experiment is 30-40ms and the integration of cellular network with WLAN using the proposed intelligent decision algorithm reduces the call dropping rate (<0.006) and call blocking probability (<0.00607) as well as unnecessary handover in heterogeneous networks.

Keywords: Vertical Handover, Fuzzy Logic, Multiple Attribute Decision Making, Context Awareness, Make before Break

1. INTRODUCTION

Mobile device data traffic consumption is increasing exponentially and it limits the quality of service provided to the user. Qualcomm (2011) has stated that network operators are attempting to address this problem by upgrading their wireless WANs and deploying femtocells. However, these upgrades increase the cost of deployment on network operator and decrease the revenue on cost per mega byte. On the other hand mobile devices are featured with Wi-Fi capabilities and Wi-Fi provides high data rate compare to cellular networks. This feature of Wi-Fi allows integration of Wi-Fi with UMTS network for seamless Wi-Fi offloading. This will reduce the number of active users on the cellular network in busy hours and gives better user experience with excellent Quality of Service (QoS). But Ding *et al*. (2013) stated that 47% of the times, 3G users are facing

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poor signal and 23% of the time Wi-Fi users are facing poor signal. This leads to poor coverage to all users and reduces data rate and implicitly increases the time duration of the data transfer and power consumption.

The development of IP based applications and mobile terminal with multiple network interfaces enables the mobile terminal to access the service from any network, at any time. Therefore these problems can be addressed by integrating all available high data rate wireless access networks.

1.1. Related Work

A number of proposals have been made for vertical handover decision algorithms. This section reviews most of the algorithms with their significance. Qualcomm (2011) designed a connectivity engine that uses Dual Stack Mobile IP for sending selected IP traffic to particular interface with support of simultaneous 3G and Wi-Fi access. But the decision engine is based on received signal strength which has already been proved as an unintelligent solution. This bottleneck is addressed in proposed approach using multiple attribute decision making algorithms. Buburuzan (2009) presented a new handover model derived from the IEEE 802.21 standard which allows the seamless integration of broadcast technologies in a wireless heterogeneous environment. But it leads to major changes in the core architecture of Cellular-UMTS architecture. The proposed algorithm applies decision algorithm over the cellular-UMTS integration architecture which does not require any change in the core architecture.

Gowrishankar *et al*. (2009) have used only bandwidth, bit error rate and network traffic for handover decision making and concluded that vertical handover problem needs an intelligent criteria based technique. The results are evaluated only based on handover dropping probability and new call blocking probability. The proposed algorithm uses fuzzy-multiple attribute decision making to gain the intelligence and the results are evaluated based on call blocking probability, call dropping probability, average handover delay and computation time. Chen *et al*. (2012) proposed a scheme based on bandwidth, dropping probability and cost parameters as the metrics for the network selection function. These values are placed in target visiting network to reduce the processing delay. The metrics collected are not stable in nature due to rapidly changing RF conditions. It requires frequent distribution of the collected metrics which increases the network traffic. The proposed algorithm handles this problem by processing the collected information locally in mobile terminal itself.

Kirsal *et al*. (2013) proposed a Markov model for cellular/WLAN integration based on the policies. This model clearly differentiates requests originating in the cellular system, from requests being handed over from WLAN to cellular system. This ensures that calls handed over from WLAN to cellular are not handed over back to the WLAN. But the prediction of user movement of this algorithm makes it complicated to deploy in mobile terminal. The proposed algorithm reduces unnecessary handover and call dropping probability by using multiple attribute decision making algorithms.

Mehbodniya *et al*. (2012) proposed a fuzzy logic based multiple attribute decision making which includes received signal strength, QoS parameters and mobile velocity attributes with analytic hierarchy process as a weighting scheme. Finally target network is selected based on TOPSIS ranking algorithm. This algorithm works fine in indoor environmental conditions. But in outdoor, it cannot perform well due to rapidly changing RF conditions. The proposed algorithm handles this problem by taking context aware strategies in decision making algorithm. Reddy and Roy (2013) proposed an algorithm based on the dwell timer for eliminating ping pong effect by reducing the shadow fading effect. But using dwell timer for individual users based on their needs is not feasible. This bottleneck is handled by using fuzzy based multiple attribute decision making algorithms for deciding when and to which network, it has to handover.

Datta *et al*. (2012) proposed Analytic network process based optimum network selection algorithm using network traffic load, velocity of mobile station, reliability, data rate, usage cost with the consideration of vehicular communication system. Lahby *et al*. (2012) proposed optimal network selection algorithm based on analytic network process and grey relational analysis.

Maaloul *et al*. (2013) and Johnson *et al*. (2013) have presented a novel context aware vertical handover algorithm based on multiple attribute decision making and the results have shown that algorithm avoids unnecessary triggered handover. But in all these approaches, the imprecision of the attributes used for handover decision cannot be handled by analytic network process. The proposed algorithm handles the imprecision of attributes by incorporating fuzzy logic with multiple attributes decision making. Marquez-Barja *et al*. (2012) used geo-location, context information and route calculation for handover decision making to improve the performance of handover. Valenzuela *et al*. (2012) has developed network selection based on the quality of experience and traffic load of the target networks. But these two approaches do not consider about the formal attributes that plays role in handover decision making.

The proposed algorithm combines fuzzy logic system with multiple attributes decision making (FMADM) to handle multiple attributes and their imprecision through fuzzy logic system. To make the decision engine more intelligent, FMADM uses the context aware strategy by taking the current status of the target network and the application resource requirements into consideration. Finally it applies "make before break handover" to minimize the packet loss during the handover.

2. MATERIALS AND METHODS

2.1. Handover Information Gathering

The input parameters from the mobile device to the algorithm includes received signal strength indicator, network coverage, mobile velocity, data rate, service cost, battery power requirements and network latency. Based on the user profile and service, the importance to these attributes will vary. This phase is done periodically for gathering information about the interface statistics, current radio environment information, application priority scores and user preferences. This collected information is used to decide whether handover is needed. These inputs are fed into decision engine for making decision about handover. Some of the collected information is static and some are dynamic as given in **Table 1**.

2.1.1. Network Related Metrics

Figure 1 shows all the handover related attributes. Network related metric includes coverage, bandwidth, latency, link quality, carrier to interferences ratio, signal to interferences ratio, bit error rate, monetary cost and security level.

Table 1. Handover information for wireless networks

Network	RSSI (dBm)	Typical downlink (Mbps)	Service cost	Mobility
GSM/GPRS	-45 to -115	9.6 to 144kb/s	High	High
UMTS	-45 to -115	3.14	High	High
Wi-Fi: 802.11b	-25 to -95	5	Low	Low
Wi-Fi: 802.11g	-25 to -95	20	Low	Low
Wi-Fi: 802.11n	-25 to -95	270	Low	Low
IEEE 802.20	Not known	1-9Mb/s	High	Very high

2.1.2. Context Aware Metrics

Context aware metric strategy includes RSSI, QoS parameters, battery status, mobile velocity, current uplink and downlink speed.

2.1.3. Terminal Related Metrics

Terminal related metric includes all parameters related to the mobile terminal and its capabilities. The parameters are mobile velocity, battery power, location information and its supported access technologies.

2.1.4. Application/Service Related Metrics

Application/Service related metric includes the type of service and its capabilities, QoS needed by the service and application profile. Some of the mentioned criteria are static and dependent on the mobile and network terminal, whereas application profile, mobile terminal velocity, bit rate, location information, coverage, bandwidth, latency, link quality, carrier to interferences ratio, signal to interferences ratio are dynamic metrics.

2.1.5. User Related Metrics

User related metrics includes all parameters related to the user profile and preferences.

2.2. Handover Decision Algorithm

The proposed algorithm uses mobile controlled vertical handover, because only mobile has the knowledge about unplanned Wi-Fi networks. Due to limited resources in mobile devices, the decision algorithm should be easily computable and should be energy efficient by means of lesser processing time. More over it should have the capability of making decision on multiple attributes for intelligent decision. Multiple attributes includes application priority scores, interface policy score and user objective scores.

To make handover decision based on the context, the proposed algorithm uses context aware scheme by collecting current network characteristics including RSSI, QoS parameters, battery status and mobile velocity. These collected metrics are assigned with the predefined weights and then passed to fuzzy based multiple attribute decision making scheme. These collected analog values from different networks are normalized into common scale (out of 10 scales) and passed into the fuzzy logic system. Analog value cannot be processed by the fuzzy logic systems (Mehbodniya *et al*., 2012); it should be converted to linguistic values.

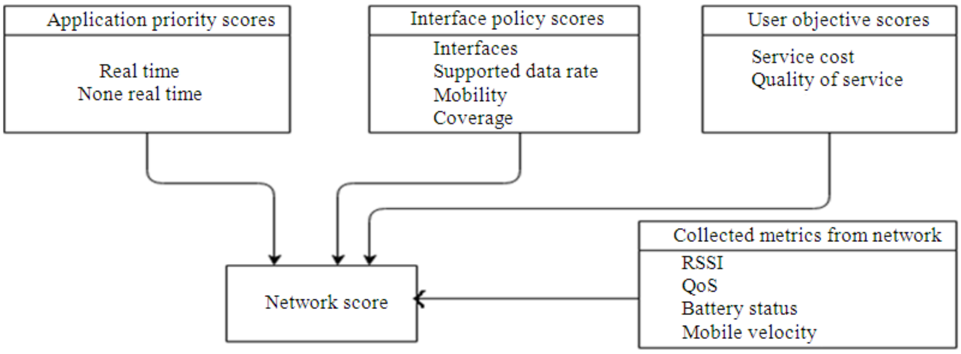

Fig. 1. Handover information gathering

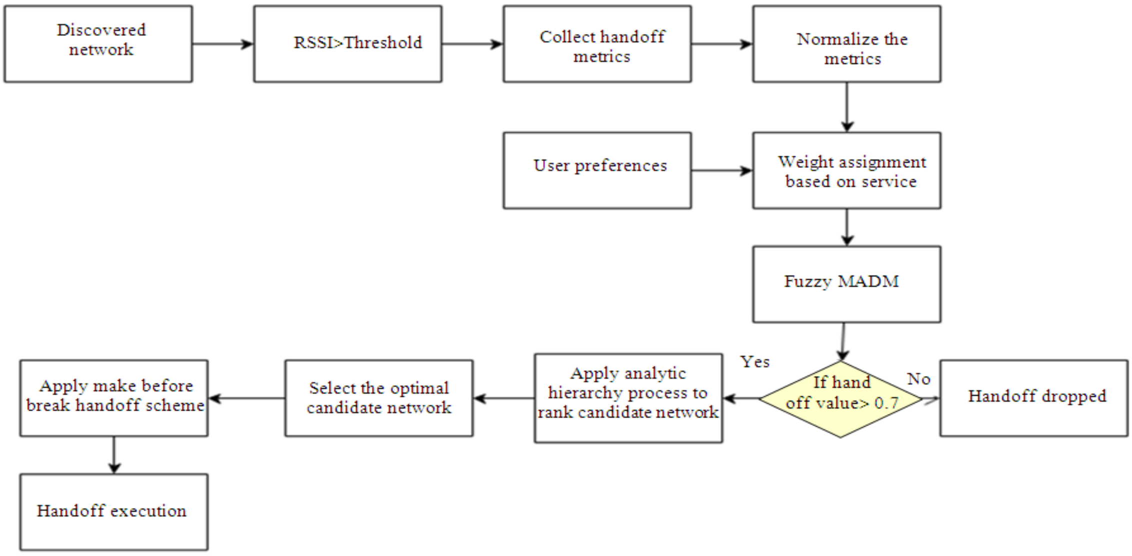

Fig. 2. Working flow of intelligent vertical handover decision algorithm

So these input parameters from the mobile node are fed into a fuzzifier and transforms them into fuzzy sets based membership functions.

These linguistic values are fed into the fuzzy inference engine. Then a set of fuzzy IF-THEN rules are applied to obtain the fuzzy decision sets. Fuzzy output decision sets include linguistic values like Strongly Yes, Yes, Uncertain, No and Strongly No. The output fuzzy decision sets are combined into a single fuzzy set and passed onto the defuzzifier to be converted into handover decision metric value. Based on this value, handover decision will be made. Fuzzy based strategy performs handover decision by choosing the appropriate time and the most suitable access network according to user preferences.

2.3. Handover Execution

Once the best suited network is identified in handover decision phase then handover execution phase makes Make before break handover and does the regular authentication and mobile IP registration. Once the selected network interface becomes active then the decision algorithm seamlessly routes the traffic to the selected interface with minimum packet loss.

2.4. Working Flow of Proposed Algorithm

Figure 2 shows the flow diagram of the proposed intelligent vertical handover algorithm. The handover information gathering phase does the network discovery in periodical manner, to identify the new network. Once a network is found, it will check whether it has the good RSSI and quality for reducing the processing for weak network. If it satisfies the threshold value then it gathers all the handover metrics.

Since different technology has different scale of metrics, it normalizes all the values in common scale. Then all the attributes are assigned with preferred weight and user preference also taken into decision criteria. These normalized parameters with preferred weight will be fed into fuzzy logic systems and to multiple attribute decision making scheme. If the candidate network gets handover probability greater than 0.7 (optimal value), then it is assigned with rank by Analytic Hierarchy Process (AHP). Based on the score of candidate network, the best network interface will be activated.

3. RESULTS AND DISCUSSION

The proposed approach has been implemented in Ubuntu based machine for measuring accurate efficiency and effectiveness of the proposed algorithm.

The proposed algorithm uses signal strength, quality of service, service cost, power requirements, mobile velocity, location information, data rate, network latency and user preferences. The proposed algorithm uses signal strength, quality of service, service and security options. The decision algorithm uses common parameters to support integration of all high data rate technologies. But currently, most of the mobile phones and laptop machines have the support for only Wi-Fi and 3G connectivity. So for implementation, only these two technologies have been taken in to account.

Weights are assigned using trial and error method by which offers better decision. **Table 2** shows the preferred weights for 3G and Wi-Fi. Wi-Fi network prefers mobile velocity and service cost while 3G prefers received signal strength and remaining battery capacity.

Figure 3 shows the utilization of resources by mobile terminal with the help of data acquired using device analyzer application. If we look at the total data used, data from 3G is higher even in presence of free Wi-Fi hotspot. It uses 3G network even if it has poor connectivity. Even in the presence of many free Wi-Fi hotspots, the mobile was depended on the 3G network for its data usage. Even under poor received signal, the mobile has transferred high data volume in 3G, which leads to heavy energy drain.

Table 2. Preferred weights for 3G and Wi-Fi

	Preferred weights for 3G network		Preferred weights for Wi-Fi network	
Handover metrics	Real time	Non real time	Real time	Non real time
Remaining battery capacity	0.154	0.148	0.154	0.148
Received signal strength	0.105	0.095	0.085	0.075
Link quality Indication	0.168	0.098	0.168	0.098
Data rate supported	0.126	0.092	0.126	0.102
Network latency	0.092	0.082	0.092	0.082
Service cost	0.088	0.088	0.108	0.102
Mobile velocity	0.113	0.213	0.153	0.213
Network coverage	0.122	0.222	0.082	0.154
Security	0.032	0.026	0.032	0.026

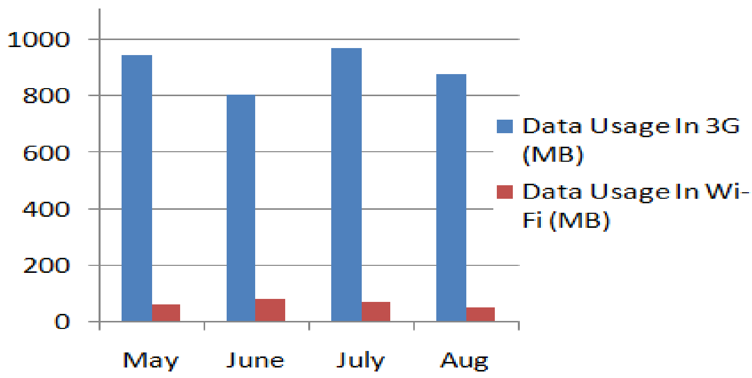

Fig. 3. Utilization of resources in mobile terminal

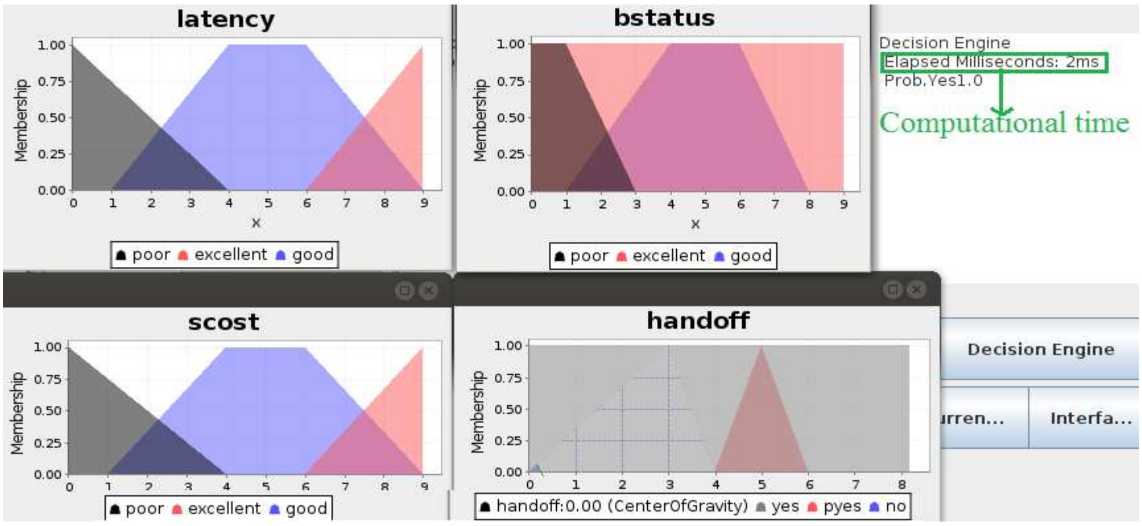

Fig. 4. Membership values of handover metrics and handover probability for Wi-Fi network from 3G

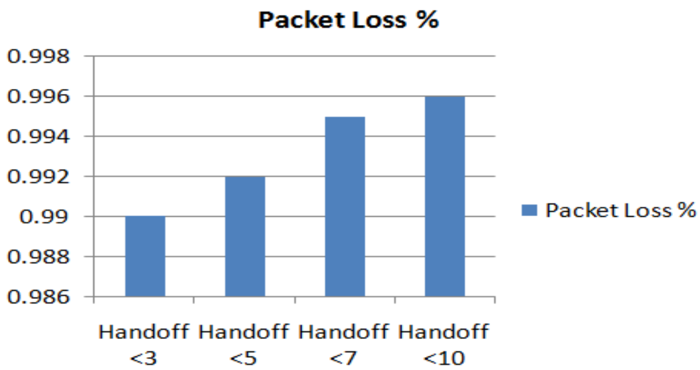

Fig. 5. Packet loss analysis of proposed algorithm

Figure 4 shows the membership of the selected handover metrics including data rate, battery status (bstatus), Network latency (latency), service cost (scost) and probability to make handover to the particular candidate network. In decision engine text area, it clearly shows that running time of this approach to make decision is just 2ms. This running time is relatively less when compared to other approaches.

Figure 5 shows that when number of handover increases the packet loss also increases due to high signaling load. But still the proposed algorithm shows it has high throughput with minimum number of packet loss. **Figure 6** show that when number of handover increases, the Round Trip Time (RTT) also increases. But it has very minimal deviation (< 4ms). The average handover delay for this experiment has been observed as 30-40 ms.

Figure 7 shows the data transferred using 3G and Wi-Fi using proposed algorithm. It clearly shows that the proposed algorithm efficiently uses the resources by switching between 3G and Wi-Fi. The proposed algorithm has been tested under different RF environmental conditions for measuring its effectiveness. Call dropping and blocking probability are the most important factor in traffic usage during the handover. The experiment was conducted with total number of 500 calls; the calling rate was 20 h, call holding time was 120 seconds, It was observed that the total number of blocked call was 3 and dropped call was 2.

Blocking Probability = (Number of lost calls)/(Total number of offered calls)

Drop call rate = (Number of dropped calls / (No of call attempts)

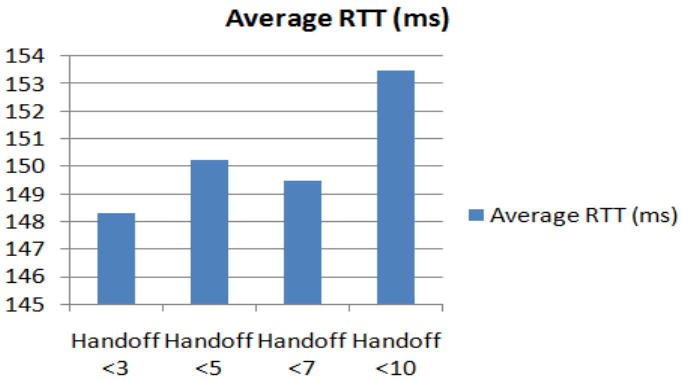

Fig. 6. Average RTT analysis of proposed algorithm

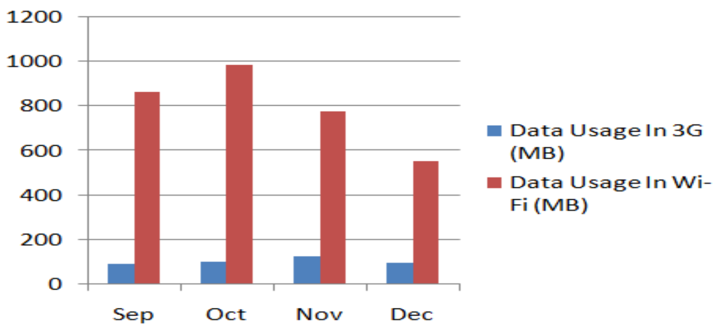

Fig. 7. Efficient resource utilization with proposed algorithm

Blocking Probability in busy hours = 3 / 494 = 0.00607
Drop call rate in busy hour= 2/500 = 0.004
Blocking Probability in busy hours with handover
= 3 / 494 = 0.00607
Drop call rate in busy hours with handover
= 3/500 = 0.006

4. CONCLUSION

The proposed approach in vertical handover decision algorithm using fuzzy logic-multiple attributes with context aware strategy enables mobile terminal to make proactive decision based on user preferences and QoS parameters. The performance analysis shows that the effectiveness of proposed algorithm in terms of minimal packet loss (<1%), running time (2 ms), handover delay (<150ms), high bandwidth and efficient resource utilization are based on the application requirements. This performance result shows that the proposed approach fulfills QoS requirements of audio, video and data in terms of packet loss, handover delay during the handover as recommended by Cisco Systems. This decision algorithm efficiently uses the network resources by switching between 3G and Wi-Fi under the different RF environmental conditions to offer best connectivity with minimal service cost to the users. It is observed that average handover delay for the experiment is 30-40 ms and the proposed intelligent decision algorithm reduces the call dropping rate (<0.006), call blocking probability (<0.00607) as well as unnecessary handover in heterogeneous networks.

The proposed algorithm categorizes the application resource requirements into real time and non real time. If application resource requirements are classified exactly based on the requirement using software agents then the algorithm would perform better. This work can be extended to reduce the load on the decision engine by routing IP traffic based on the policy and synchronizing schedule of users. User's profile and usage pattern can be learned using unsupervised learning algorithms instead of using rule based multiple attribute decision making in the decision engine for the future work.

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