Artificial intelligence techniques in handover decision: a brief review

Colaboración
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ABSTRACT: In this paper we present an analysis of intelligent artificial techniques applied to handover decision. Besides, we do an analysis of handover process by OSI model and the solutions from application layer, network and link. Our contribution to the state of the art is update intelligent artificial techniques adding ontologies. Besides, this paper is an overview of the active research topics in Handover.

KEYWORDS: Handoff decision, ANN, Fuzzy logic, Ontology, Inteligent artificial

INTRODUCTIÓN

The conception of the Internet was born from the Advanced Research Projects Agency (ARPA) in 1957, with the collaboration of Leonard Kleinrock et al, developed the ARPANET [1]. Afterwards, several researchers joined the development of the internet and it is conceived as a network of static networks. But, later with the evolution of the network of networks, wireless devices appear and with them the problem of mobility. That is, problems related with the physical change of the network and the problems inherent to the loss of continuity of services.

This work focuses on the investigation of mobility in IP networks, mainly in the handover procedure, its stages, protocols and applied techniques of artificial intelligence in decision making. That is why, an analysis is made from the perspective of each of the stages of the handover and it contributes to the classification of the proposals by the OSI model layer and the artificial intelligence techniques are updated in the decision making process.

This article is organized as follows, section 2 deals with the handover and its types, later in section 3, the process of acquiring network metrics is illustrated, later in section 4, the decisionmaking algorithms and their classification are mentioned. Then, in section 5, the execution of the handover and some of the most commonly used protocols, in section 6, there is an analysis and discussion of the proposals to show the conclusions in section 7.

HANDOVER IN IP NETWORKS

The handover or handoff in IP networks is the physical transition from one network to another. The handover is typified in two types of transition 1) handover horizontal and 2) handover vertical [2] When a Node Mobile (NM) changes of network in the same technology it performs a horizontal handoff. As shown in the dotted box of Fig. 1. But, if it changes of network with a different technology then perform a vertical handoff. So as shown in the vertical box of Figure 1.

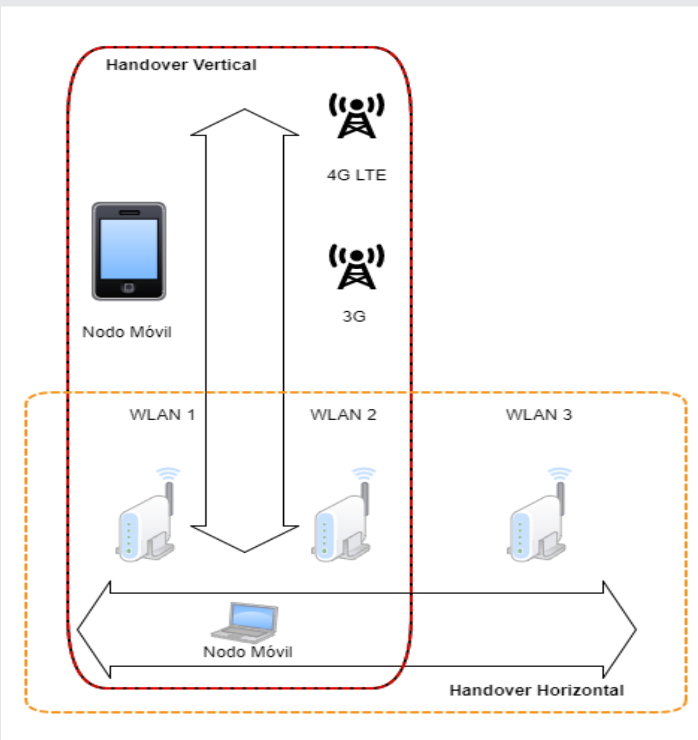

Figure 1. Vertical and horizontal handover, own elaboration.

The general procedure of the change process is classified in three stages according to [3] and [4], 1) Measurement of handover and initialization, 2) Handover decision and 3) Execution of the handover. In the first stage, the NM takes measurements of the metrics of the next networks, in the second stage, algorithms decide when to change networks and in the third stage, the necessary procedures are carried out to connect to the new network and reestablish the services, as well as it is shown in Figure 2.

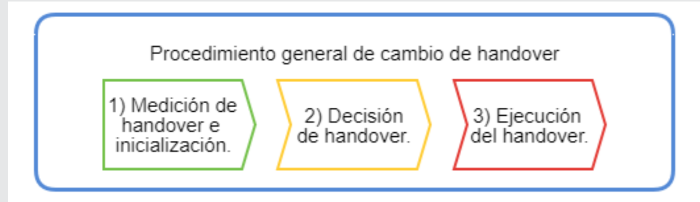

Figure 2. General procedure of the handover, own elaboration.

MEASUREMENT OF HANDOVER AND INITIALIZATION

In this first stage, the MN needs to find a potential network within its range, then it is necessary to scan the networks within its scope. In IEEE 802.11 networks [5] the process is divided into three stages: 1) Scanning, 2) Authentication and 3) Reassociation. In the scanning stage, the mobile node needs to find a potential access points within its range, this action can be carried out passively or actively [6]. In the active process, the mobile node sends a broadcast probe request message for each channel, then activates the probe timer and if it does not receive a response before the temporscope reaches MinChannelTime, the mobile node considers that there is no access point in that channel and it will have to scan another channel. Similarly, if the MN detects that the channel is not hidden, it must wait for a probe response message until the timer reaches the MaxChannelTime. Empirical measurements show that the MinChannelTime is approximately 20ms and the MaxChannelTime is approximately 40ms [7]. On the other hand, in the passive process the wireless network card waits for beacon type messages, sent periodically by the Access Points (APs) every 100ms in each channel, as the 802.11 standard has 14 channels but for Latin America only 11 channels they are used [8], then there is a greater time than a second of latency of scanning, conditions not favorable for applications in real time in WiFi networks.

Once the MN discovers the potential access points, so that it can enjoy the services offered by the AP, it must be authenticated and associated. Broadly speaking, a node can be authenticated or not depending on the security scheme, that is, if the system is open (Open system), supports any host without authentication. Otherwise, it supports only MNs that know the password (Shared Key). Finally, the association process consists in the exchange of two messages between the AP and the MN: association request and association response. Once the node receives the message the association response is ready to send and receive messages through the AP.

HANDOVER DECISION

The algorithm responsible for making the decision is one of the stages that directly influences the performance of the handover. Basically, at this stage it is decided to which network is going to change, multiple algorithms have been proposed in the literature that use schemes based on Received Signal Strength (RSS), Quality of Service (QoS), decision functions based on multicriteria and algorithms based in artificial intelligence techniques. In general terms, the decisionmaking algorithm is fed from the data provided by the network, after processing the data, then decides which network to change, this idea is illustrated in Figure 3.

Some of the criteria most used to make the decision to change are: Received Signal Strength Indicator (RSSI), power level of the signals received in wireless networks, Network Load (NL), the traffic load in a network can be an important parameter by the channel capacity, Bit Error Rate (BER), It is the number of received bits that have been altered due to noise or interference, divided by the total number of bits transferred during the time of the interval. Throughput, this measure refers to the amount of data or messages it receives successfully, in a specific channel, Signal to Noise Ratio (SNR), is defined as the ratio between the signal power that is transmitted and the power of the noise that corrupts it. In addition, user preferences such as the cost of the network and security.

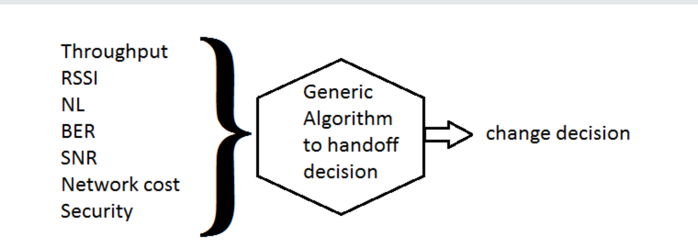

Figure 3. Generic algorithm for change decision making, own elaboration.

The trend in the literature reviewed shows that the networks will be more heterogeneous, in this way, a vertical handover will be more common. By making a synthesis of some of the revised algorithms, they are classified based on the main criteria they use to make the decision.

ALGORITHMS BASED ON A DECISION CHARACTERISTIC

Algorithms RSSbased. Algorithms based on the strength of the signal only, are easy to impzlement due to their unique criteria. But, they only serve to unleash the handover process, because it is very sensitive to change, when it finds a network with better RSS, it triggers a new handover.

In horizontal handover it is common to use the RSS as the only parameter of change. The iconic algorithm of this scheme is the “greatest potential” algorithm [10]. In essence, it makes a change to the network that has the most RSS, because it has greater reception than the previous network and in theory that implies a smaller packet loss, however this algorithm generates a pingpong effect, which causes the opposite.

The pingpong effect consists of performing unnecessary handovers and increases the handoffrate (handoff number during a data session). Multiple authors try to reduce the pingpong effect, using thresholds [11]. On the other hand, in [12] they use Received SignaltoNoise Interference (RSNI). All the previous proposals try to reduce the number of unnecessary handovers.

Algorithms based on bandwidth. This type of algorithm is governed by the principle of switching to networks with a better bandwidth to obtain a better throughput in vertical handover, as in [13] that presents a proposal for a soft vertical handoff and in [14] that propose an algorithm of decision making based on the bandwidth for a vehicular network ad hoc networks (VANET)

ALGORITHMS BASED IN ARTIFICIAL INTELLIGENCE

Algorithms based on Artificial Neural Networks (RNA).
The neural networks in the handover have been applied to solve the change decision making in heterogeneous networks. In [15] they propose an artificial backpropagation neural network using the RSS input parameters and the traffic intensity in the target networks, supervising the training of the network, however the delay caused by the training stage is a problem. Otherwise, in [16] a Middleware based on an RNA is proposed to select the best network based on user preferences, however, it increases the latency during the execution of the handover due to the size of the signaling packets used and the training time. Another current proposal in [17] proposes a neural network with RSSI input parameters and the speed of the mobile node, reducing the number of unnecessary handover.

Algorithms based on fuzzy logic.
Vertical handover algorithms involve several factors and some factors can hinder quantification. Fuzzy logic can be applied to solve change decision problems with parameters that can be fuzzified. Some proposals, such as [18-21], use these policies to make change decisions and at the same time try to balance the burden of the networks efficiently. Using the input parameters such as RSSI, latency and data rate.

Algorithms based on Ontologies.
In 1993 Gruber defined in [22] the term of Ontology, according to him it is known as an “Explicit and formal specification of a shared conceptualization”. In this research topic, proposals are developed as in [23] that propose an Ontological knowledge base for an appropriate selection of network, depending on the RSS parameters, bandwidth and network cost, managing to reduce the pingpong effect.

In [24] they propose the use of ontological domains for handover in such a way as to structure the information to provide a semantic meaning in such a way that it determines a common vocabulary that reduces the complexity in the decision making.

Algorithms based on Deep learning.

Deep learning according to [32] allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction. In this context approach as [33] presents a machine learning based handover management scheme for LTE to improve the Quality of Experience (QoE) of the user in the presence of obstacles. In other hand, a deep learning based handover mechanism for UAV networks [34], they use a trajectory prediction model based on neural network to improve network performance.

EXECUTION OF HANDOVER

This section deals with representative execution protocols and presents some of the proposals reviewed in the literature from the OSI model approach.

There are different preferences in the handling of the handover procedure, some prefer the network layer and others the application layer. In the same way there are reactive and proactive proposals. That is, there are protocols that anticipate their arrival to the new network to avoid delays and loss of packages that are proactive proposals. In another scenario, the protocols that take measures after the transfer are reactive.

Analysis from the application layer

The seven layer of the dominant protocol is the Session Initiation Protocol (SIP). The SIP protocol [26], is able to support the mobility of terminals, mobility of sessions, personal mobility and mobility of service, in addition SIP has been widely accepted as the signaling protocol in the new wireless networks, therefore SIP seems to be an attractive candidate for the management of communication services in heterogeneous IP wireless networks at the application level, however, SIP implicates the processing in the application layer introducing a considerable delay. In this layer, experts agree that the main contributor to delay is the stage of acquiring IP addresses, because they use the Dynamic Host Configuration Protocol (DHCP), and in this protocol there is a procedure called Duplicate Address Detection (DAD) that avoids duplicated IP addresses in the network, taking between 1 to 3 seconds.

Analysis from the network layer.

The network layer seems to be preferred to handle IP mobility, basically when it comes to mobility at the network level, we must speak of Mobile IP (MIP), since MIP is the protocol representative of this layer. It was originally proposed by C. Perkins, et al. [27], in 1996, since then many researchers have contributed to improve the protocol.

Mobile IP defines three basic components: 1) Mobile Node, 2) HA (Home Agent) special entity located in the node´s originating network, the HA knows at all times where the MN is and finally the 3) FA (Foreign Agent), another special entity located in the destination network, in charge of delivering the packages addressed to the MN. These components cooperate to locate and record the current IP address of the MN that moves through different IP subnets(Hamdaoui,2004), that is, it is designed to provide a transparent packet transfer service for higher layers, commonly using the tunnelling protocol [27].

This process consists of two phases: 1) "agent discovery" and 2) "registration". Agent discovery is the period where the MN detects that it is moving from one subnet to another and obtains a new address, called CoA (CareOfAddress) [29]. On the other hand, the Registration procedure consists of informing the HA of the MN CoA, in order to keep the IP address of the MN updated and to forward the packets from the originating network to the destination network using a virtual tunnel [30].

ANALYSIS AND DISCUSSION

In this section a comparative table of the different proposals presented in this article is presented. Segmented by handover stage.

Table 1. Comparison of proposals of stage 1) Measurement of handover and initialization. Own elaboration.

proposal	Name of the proposal	Year	Technologies	Loss of packages	Scan time	Handover time layer2
5	Practical schemes for smooth MAC layer handoff in 802.11 wireless networks.	2006	802.11	4 packages	1.1s	40 ms
6	An empirical analysis of the IEEE 802.11 MAC layer handoff process	2003	802.11	-	500ms	48.5 ms
7	A neighbor caching mechanism for handoff in IEEE 802.11 wireless networks	2007	802.11	-	2.4 s	50ms

Table 2. Comparison of proposals of stage 2) Decision of handover

Proposal	Name of the proposal	Year	technologies	Input values	AI Technique
9	Novel framework for proactive handover with seamless multimedia over WLANs	2014	802.11	RSS	-
11	Analysis of Vertical Handover Based on RSS and QOS Parameter. Networking and Communication Engineering	2015	802.11	RSS	-
12	A softer vertical handover algorithm for heterogeneous wireless access networks	2010	UMTS-WLAN y WiMAX-WLAN	Bandwidth	-
13	Vertical handoff decision algorithms for providing optimized performance in heterogeneous wireless networks	2009	GPRS/UMTS WLAN	Bandwidth	-
15	Middleware vertical handoff manager: A neural network-based solution	2007	4G, WLAN, 802.16	cost, security, power consumption, network conditions	RNA
16	Handover Decision in Wireless Heterogeneous Networks Based on Feedforward Artificial Neural Network. In *Computational Intelligence in Data Mining*	2017	-	RSSI, Mobile speed	RNA
17	An adaptive fuzzy logic based handoff algorithm for interworking between WLANs and mobile networks	2002	WLAN, UMTS	RSS, speed	Fuzzy logic
18	A novel fuzzy logic vertical handoff algorithm with aid of differential prediction and pre-decision method	2007	UMTS WLAN	RSS, speed,	Fuzzy logic
19	Vertical Handoff Decision Using Fuzzification and Combinatorial Fusion	2017	Wi-Fi, 4G	RSS, Data rate, network delay	Fuzzy logic
20	Fuzzy multiple attribute decision access scheme in heterogeneous wireless network	2017	3GPP , WLAN	QoS, network link, cost	Fuzzy logic
22	Towards a knowledge-based intelligent handover in heterogeneous wireless networks	2010	-	RSS, bandwidth cost , user preferences	Ontologies
23	DOHand: An ontology to support building services to exploit handover information in mobile heterogeneous networks	2006	GSM, UMTS, Wi-Max, WiFi	Ontologies	

The proposals in Table 1, try to reduce the scanning time, in this way reduce the link layer handover. Otherwise, in the decision stage of handover (see, Table 2), most of the proposals use RSS as a decision parameter, but they add some other features to avoid the pingpong effect. Also, it can be observed that fuzzy logic and RNA are the most used artificial intelligence techniques and the horizontal handover was performed between UMTS and WLAN, now with the evolution to 4G, it is performed in LTE and WLAN, although not limited to these technologies. In general terms, the scientific community continues to investigate this topic of research, as can be seen from the years of publications.

CONCLUSIONS

Networks are increasingly heterogeneous, mobile nodes acquire more connection, processing and storage interfaces. In this way the quality of the communications improves and the investigations converge in making faster the transfers from one network to another, avoiding the loss of packages. In terms of the general procedure of the handover, 1) Measurement of handover and initialization, the researchers try to reduce the time of scanning and acquisition of metrics for the next phase. 2) Handover decision, this stage multiple artificial intelligence proposals have been proposed, among the most popular are neural networks but the training time does not help to reduce handover latency. But, simpler proposals generate the pingpong effect if only one parameter is used as the RSS. That is, there must be a balance between temporality and quality of service. Finally, in stage 3) Execution of the handover, researchers continue to develop new protocols to minimize the signaling and delay generated by the handover execution procedure.

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