Entity Title Architecture Extensions Towards Advanced Quality-oriented Mobility Control Capabilities

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***Abstract*—The emergence of new technologies, in addition with the popularization of mobile devices and wireless communication systems, demands a variety of requirements that current Internet is not able to comply adequately. In this scenario, the innovative information-centric Entity Title Architecture (ETArch), a Future Internet (FI) clean slate approach, was design to efficiently cope with the increasing demand of beyond-IP networking services. Nevertheless, despite all ETArch capabilities, it was not projected with reliable networking functions, which limits its operability in mobile multimedia networking, and will seriously restrict its scope in Future Internet scenarios. Therefore, our work extends ETArch mobility control with advanced quality-oriented mobility functions, to deploy mobility prediction, Point of Attachment (PoA) decision and handover setup meeting both session quality requirements of active session flows and current wireless quality conditions of neighbouring PoA candidates. The effectiveness of the proposed additions were confirmed through a preliminary evaluation carried out by MATLAB, in which we have considered distinct applications scenario, and showed that they were able to outperform the most relevant alternative solutions in terms of performance and quality of service.**

I. INTRODUCTION

The emergence of new technologies such as the Internet of Things and Cloud Computing, in addition to the significant growth of mobile devices with multiple access capabilities, has led to a number of requirements, such as mobility and reliability, which the Internet is currently unable to satisfy effectively [1]. The attempts to enhance the Internet of today and address new emerging demands, has resulted in a sharp increase in its complexity whilst jeopardizing its performance and scalability. In this context, there have been several attempts by researchers to focus on Internet redesigns [2][3], a.k.a. *Future Internet* (FI), and to adopt a new approach that is completely re-architected with new services, mechanisms and protocols to deal with new capacities.

Among these initiatives, the *Entity Title Architecture* (ETArch) [4] is a promising FI clean-slate architecture that employs a new naming and addressing scheme based on the Title, and shares the vision of content-oriented paradigms. It is a realization of the Entity Title Model [5], and consists of a vision of how the entities should be able to semantically specify their requirements and capabilities so that they can communicate with each other. ETArch can inherently support mobile group-communication based on the OpenFlow [6] substrate within the Workspace, a channel that is able to gather two or more communicating participants.

ETArch has been recently enhanced with seamless mobility optimization control capabilities, by being integrated with enhancements inspired by the IEEE 802.21 *Media Independent Handover* (MIH) Standard [7][8]. In this way, Workspace establishment mechanisms become aware of new network connection points detected by *Mobile Nodes* (MN), as well as their characteristic semantics (e.g., capacity and conditions), and use this information to enhance the handover process in the network. Moreover, the network is also able to use these mechanisms to monitor network-based features (e.g., load in a cell), and handover-affected terminals to better-performing network connection points.

ETArch architecture and its main components are presented in Figure 1. The DTSA, that acts as an OpenFlow controller and as the *Point of Service* (PoS) of the network, is responsible for storing information about the existing entities (Entity Manager) and workspaces (Workspace Manager), and also handling and controlling mobility procedures (Mobility Manager). The EDOBRA Switch consists of an IEEE 802.21-enabled OpenFlow switch and the Mobile Node represents the end-user equipment, and may be equipped with one or more access technologies, either wired or wireless. More information about ETArch components and their relationship can be found in [1][4].

As a result, despite being Media Independent in nature in terms of their ability to operate independently of the underlying access technology (both wired and wireless), the ETArch mobility control mechanisms [1], are currently only based on link layer features. Although the IEEE 802.21 Standard provides access to events associated with link quality, (such as its ability to indicate the support and characteristics of differentiable *Classes of Service* – CoS in the link, and minimum/maximum delay/jitter experience, among other factors), the ETArch mobility control currently triggers the handover process solely on the basis of the *Received Signal Strength*

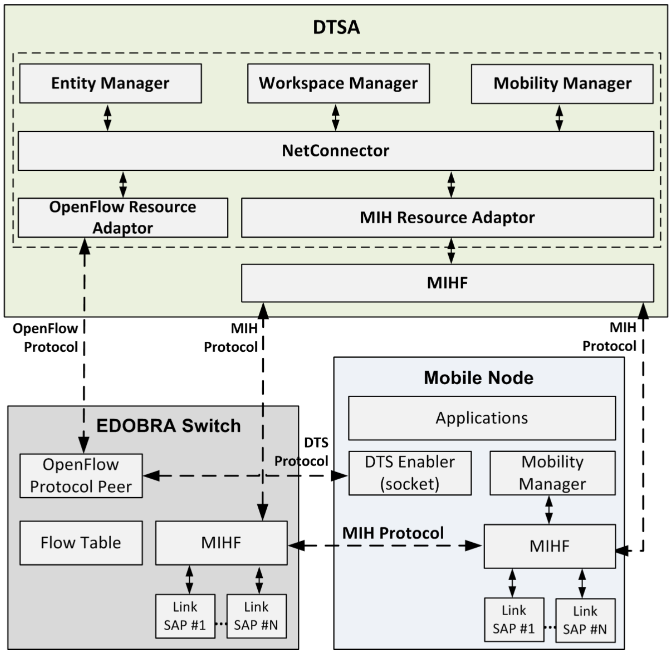


Figure 1: ETArch main components

(RSS) of the candidate *Points of Attachment* (PoA).

In other words, a MN triggers the ETArch mobility control after detecting that the RSS of the current PoA is low, whilst the RSS level of the neighbouring PoAs is higher, and denotes that the MN is moving. The Mobility Manager in turns decides that the best PoA (among other neighbouring PoA handover candidates) is the one that has a better RSS, and can thus proceed with the handover setup functions. In a similar way, the mobility manager in the network itself can trigger handover procedures by means of network-based stimuli, such as increases in cell load.

Despite this innovative approach, ETArch does not consider reliable communications provisioning in its design, and omits important factors for determining the connection such as the quality requirements of demanding applications, as well as the level of quality of the network nodes. Thus, ETArch lacks quality-oriented mechanisms for establishing Workspaces, which means that network control functions seriously restrict data dissemination to the best-effort transport model of the current Internet. These procedures are insufficient to ensure that the mobility process towards new network connections will improve service performance. For instance, the optimal handover procedure for the MN requires it to be triggered in the presence of a degration of data transmission quality (e.g., excessive packet error/loss rates), which means that it is not necessarily guided by mobility factors, when assigning another PoA with a better level of quality.

It is evident that ETArch is unable to accommodate bandwidth-intensive mobile session flows (e.g., real-time multimedia) that can guarantee both *Quality of Service* (QoS) and *Quality of Experience* (QoE) over time, in terms of keeping wireless connections with limited delay, error and loss rates experience. This drawback will seriously restrict the scope of ETArch in future Internet scenarios, especially when account is taken of the fact that traffic forecasts [9] predict that 80% of the total data flows will stream multimedia content by 2017. In view of this, the mobility control functions of ETArch must take into consideration alternative parameters to link layer-based ones (e.g., user preferences, MN capacities, minimum application and service quality requirements, etc.) to guide quality-oriented seamless mobility.

The limitations described above justify our work in the sense that there is a need to extend the mobility support of legacy ETArch with quality-oriented mechanisms for both prediction and handover control functions. First of all, we attempt to define the application session requirements that semantically describe the quality demands that must be fulfilled over time. Moreover, we set out the *Extended Elitism for Best Selection* (E2BS) proposal, which extends the Elitism Selection Strategy [10] by combining it with *Multi Attribute Decision Making* (MADM) [11] features to achieve efficient quality-oriented mobility control decisions that can meet the quality demands of mobile session flows and current wireless conditions of PoA(s) candidate(s). In addition to the current RSS-based scheme, we will make use of the flexible nature of the ETArch framework, and empower its handover management scheme so that it can be applied not only to quality-oriented link layer parameters, but also to high level (e.g., application and user) parameters for enhanced handover decisions. Thus, we seek to maintain best connectivity over time, and be able to make decisions that go beyond those that are strictly guided by the motion events of MN.

Although this work is inserted under ETArch project, its main purpose is to evaluate and compare the performance of our proposed decision method with the most related relevant alternatives in order to expose the performance of our approach.

The remainder of the document is structured as follows: Section 2 sets out the vertical handover decision problem and conducts an analysis of related work. Section 3 provides an overview of the E2BS proposal. Section 4 provides a preliminary evaluation of E2BS. And Section 5 examines the outcomes and make suggestions for future work.

II. Related Work

The handover process basically involves four different phases of operation: (i) Handover initiation; (ii) System discovery; (iii) Handover decision; and (iv) Handover execution [12]. The process begins in the handover initiation phase, with detecting alterations to pre-defined criteria parameters, such as the RSS, battery lifetime, available bandwidth, among several others. Afterwards, the system discovery phase is invoked, and seeks to gather information about neighbour networks (i.e., PoA candidates) as from the MN scan.

The information gathered during the system discovery phase is used to support the handover decision phase. The handover decision is applied by means of an appropriate algorithm, which is employed to choose the most suitable PoA at the moment when the MN is under the handover influence. Finally, the handover execution phase is responsible for enforcing the wireless connection setup between the referring MN and the new PoA, as well as to release all connections with and the previous PoA seamlessly (i.e., those deployed by the network infrastructure).

This means that, the handover decision phase is a key factor in keeping the MN best connected, whereas its efficiency depends on the mobility parameters taken into account. In order to enable quality-oriented decisions, a handover algorithm is required to take into account both the minimum quality requirements of the mobile session flow (bitrate, tolerance to packet delay/loss/error, etc.) and the current wireless link conditions of the PoA candidates (available traffic classes, packet delay/loss/error current rates, wireless technology, etc.) [13]. An efficient approach to quality-oriented mobility control must always keep the mobile nodes best connected over time, and guarantee that the whole activated mobile session flow meets their quality requirements even under the handover influence of the handover procedure. The literature provides a number of quality-oriented mobility control solutions, and an analysis of the most significant ones can be found in the following.

The *Multiple Attribute Decision Making* (MADM) techniques are employed in the most important mobility control algorithms to address the handover decision problem [14]. When formulating a mobility control algorithm that follows a MADM [15] approach, the handover decision problem can be expressed in a matrix format, where the j^{th} attribute of the i^{th} alternative is represented as x_{ij}. In the case of a quality-oriented handover decision, the alternatives are the candidate networks and the attributes are the required quality parameters. The networks are ranked by the use of scoring techniques, which attach different importance values (weights) for each parameter [16].

There are several MADM methods which are widely used to deal with the handover decision problem. Here we briefly describe some of them and their related applications.

A. Analytical Hierarchical Processing

The *Analytical Hierarchical Processing* (AHP) method is mainly used to determine the criteria for weighting the attributes. Its mechanism allows evaluations of intangible qualitative criteria to be incorporated alongside tangible quantitative criteria by making a synthesis of priorities [17].

B. Simple Additive Weighting

The basic operation of *Simple Additive Weighting* (SAW) consists of calculating the weighted sum of all the considered metrics, where the score of each candidate network i is given by the standardized values of each considered metric v_{ij} multiplied by the weight w_j [11].

In [18], a handover decision mechanism is proposed that uses the SAW method through the IEEE 802.21 Standard, and adopts user preferences as cost parameters to decide how the candidate networks should be classified.

C. Technique for Order Preference by Similarity to Ideal Solution

The main goal of the *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS) is to choose the alternative which has the closest similarity to an ideal case solution and is farthest from the worst solution [16][19].

In [20] is proposed a vertical handover algorithm which combines the parallel decision of fuzzy logic and TOPSIS multiple criteria decision making capability with the goal to improve network quality of service and optimize the handover process in the network.

D. Multiplicative Exponential Weighting

The computed score of *Multiplicative Exponential Weighting* (MEW) is calculated by the weighted product of the attributes [11].

In [21] an improved MEW algorithm called SLE-MEW is proposed for vertical handover decisions in heterogeneous wireless networks. This introduces the signal to interference plus noise ratio (SINR) effects and information entropy method into the algorithm. The handover decision that is made to meet multi-attribute QoS requirements depends on the traffic features.

E. Grey Relational Analysis

The *Grey Relational Analysis* (GRA) method ranking computing is performed by the data standardization to deal with benefit and cost metrics and a *Grey Relational Coefficient* (GRC) calculation is carried out for each network. The GRC is the score that is used to account for the similarity between each candidate network and an ideal network. The chosen network is the one with the greatest similarity to an ideal network [19].

In [22] the authors proposes a novel QoS-based network selection algorithm that integrates AHP and GRA so that they can address weighting factors and network prioritization, respectively.

Although several studies have explored the quality-oriented mobility control field extensively, there are extremely few which propose or explicity deal with it within the framework of an FI integrated architecture. Furthermore, many studies that address the vertical handover problem do not take into account the particular features of CoS within the heterogeneous technologies so as to be able to provide a seamless handover.

III. Overview of the Proposal

E2BS is a handover decision method inspired in the Elitist Selection Strategy [23], combined with MADM features to enable quality-oriented mobility decisions efficiently. Its main goal is to meet both the quality requirements of active mobile session flows and to match the current quality standards of neighbouring PoA candidates.

The elitism strategy employed by E2BS is based on a multi-attribute evaluation of the QoS candidate networks. In our model, the population is represented by a set of PoAs and their attributes. This technique is used to select the PoA which offers the best connection criteria. Assessing the QoS offered by the various PoA to select the best one is carried out by measuring the similarity [24] between the attributes of the elite individual, represented by the reference PoA, and other candidates. The reference PoA is considered to be the one that have the ideal values, (i.e. attributes like delay and jitter should have values close to zero).

Based on the MADM approach, E2BS was designed to deal with the attribute importance (weight) of diverse applications by means of different traffic classes with distinct requirements [25].

Table I: CoS mapping policy for heterogeneous wireless technologies

	CoS ID	3GPP UMTS	IEEE 802.11e	IEEE 802.16e	QoS requirements	Typical applications
QoS traffic class	1	Conversational	AC_VO	UGS	Very delay sensitive	VoIP
	2	Streaming	AC_VI	rtPS	Low jitter and high bandwidth	Video Streaming
	3	Interactive	AC_BE	nrtPS	Error rate sensitive and throughput guarantees	FTP
	4	Background	AC_BK	BE	Error rate sensitive and maximum sustained throughput	Background traffic (download of Emails)

The following stages are required to compute the scores of the candidade networks:

1) The QoS attributes of the candidate networks are joined to compose the decision matrix;
2) Since the data value of the attributes is expressed in different formats, there is a need for standardization:

$$\parallel x_{ij} \parallel = \frac{x_{ij} - \bar{x_j}}{\sigma_j} \tag{1}$$

Where $\bar{x}_j$ is the arithmetic average and σ_j is the standard deviation of the attributes, respectivelly.

3) Traffic class importance weight assignment is applied according to the respective traffic classes:

$$v_{ij} = w_j * \parallel x_{ij} \parallel \tag{2}$$

4) The final score is computed by calculating the Euclidean distance between the attributes of the reference PoA and other candidates:

$$d_{ij} = \sqrt{\sum_{j=1}^{n} (v_{ij} - r_{ij})^2} \tag{3}$$

5) The selected network is that which has the highest final score:

$$S = MaxScore(d) \tag{4}$$

The handover prediction technique plays an important role in the mobility control mechanism architecture, since it can predict service disruption events in advance as well as enable the handover triggering and thus allow a better network selection. A quality-oriented handover prediction scheme encompasses the monitoring of the network quality attributes which assists the handover decision phase to choose the appropriate PoA.

Our handover prediction model makes use of ETArch content-oriented capacity in which all the applications have to specify their communication requirements. In this way it is possible to identify failings in the network quality session and allow the handover decision mechanism to be triggered appropriately. The process starts by defining the quality requirements at ETArch: If the network quality session exceeds the threshold of the application, MN is asked to scan the surrounding networks and its quality attributes will form the decision matrix of E2BS.

IV. Preliminary Evaluation

Simulations were carried out in MATLAB to evaluate our proposal. We consider a scenario that integrates six candidate networks, which are: 3GPP UMTS, IEEE 802.11 and IEEE 802.16, with two of each. Since different applications have different quality requirements we have considered four QoS CoS for each network type.

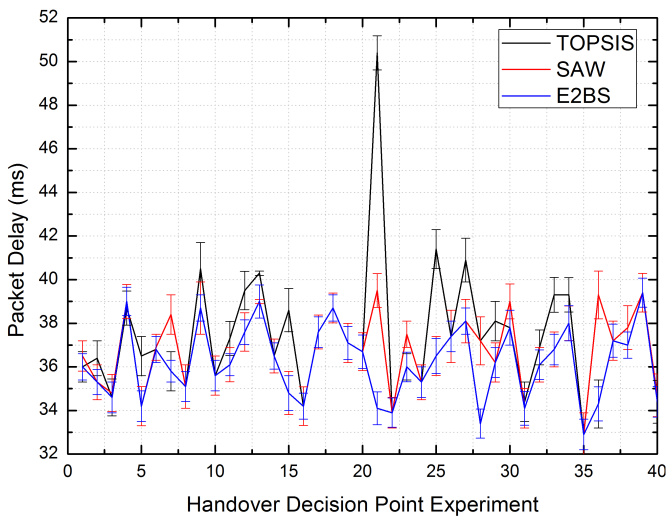
The 3GPP technical specification [25] define four traffic class for UMTS. The Conversational class is suitable for applications which are very delay-sensitive like *Voice Over IP* (VoIP). The Streaming class has low jitter and high bandwidth requirements (e.g. Video Streaming). Interactive and Background classes are error-rate sensitive due to their channel coding and retransmission techniques and are used by traditional Internet applications like FTP, Email and Web Browsing. The main difference between Interactive and Background classes is that they are used for interactive applications (e.g. interactive Email) and background traffic (e.g. background file downloading) respectively.

The IEEE 802.11e Standard [26] defines four CoS for different types of applications: AC_VO (*Access Category Voice*) for voice traffic; AC_VI (*Access Category Video*) for video streaming traffic; AC_BE (*Access Category Best Effort*) for best effort traffic and AC_BK (*Access Category Background*) for background traffic like the downloading of Emails.

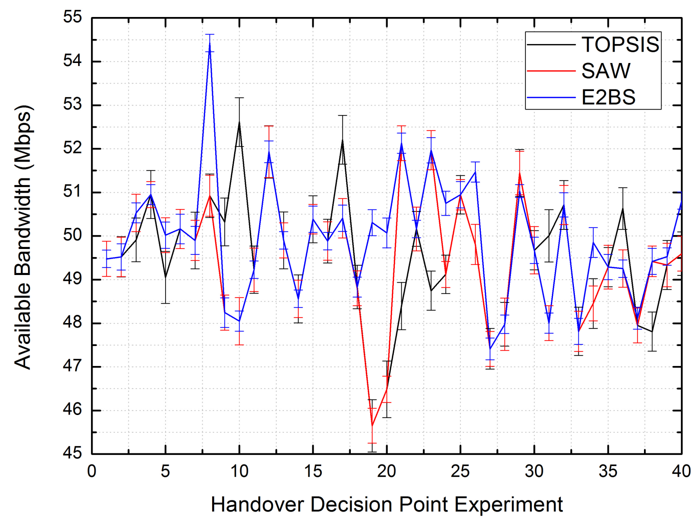
The IEEE 802.16e Standard [27] defines five CoS for five different types of applications. In this study we only consider four: UGS (*Unsolicited Grant Service*) for voice service; rtPS (*Real-Time Polling Service*) for video streaming; nrtPS (*Non-Real-Time Polling Service*) for applications like FTP and BE (*Best Effort*) for data transfer without QoS guarantees.

To ensure seamless handover between heterogeneous networks, it is necessary for the applications to become aware of the new CoS in the new network. This is done through a remapping policy between the origin and destination classes, so that the data source can send data from the new class. The remapping policy groups the different CoS of the considered networks in CoS ID according to their characteristics and requirements, as shown in Table I.

The methodology employed in the evaluation experiments of the simulations, were conducted to assess the performance of E2BS in VoIP and Video streaming application scenarios. The scenarios were compared with two of the most significant related work (i.e., algorithms adopted for handover control): SAW and TOPSIS. This was achieved by taking account of the four QoS parameters used by E2BS for the session-flow



(a) VoIP application



(b) Video streaming application

Figure 2: Packet delay and available bandwidth for VoIP and Video streaming applications

quality requirements, so that they could support the handover decisions: Packet delay, Packet jitter, Available bandwidth and *Bit Error Rate* (BER). The generation of these handover decision parameters for the candidate PoAs follow the experiments conducted by [16] and [19], and were randomly placed for typical operational and standardized ranges.

Table II: Importance weight values

CoS ID	Packet Delay	Packet Jitter	Bandwidth	BER
1	0.450	0.450	0.050	0.050
2	0.114	0.424	0.424	0.037
3	0.161	0.043	0.161	0.636
4	0.055	0.055	0.220	0.669

The values of the importance weights were determined by the AHP method which consider the relevance of each attribute requirement at each CoS: Each attribute was combined with a description of its relevance to a given class and the importance weights are derived by means of this qualitative analysis. Table II show the importance weight value for each attribute and its respective CoS.

The simulation was carried out by considering 40 handover points (i.e the point of the specific handover decision phase) with six available candidate PoAs in each one. Each attribute value that was generated, was assigned to the respective PoA, and this resulted from an average of 20 randomizations trials. The following results were obtained from an average of 50 simulations for each handover point.

Figure 2 shows the performance of E2BS in comparison with the SAW and TOPSIS-based solutions in VoIP and Video streaming application scenarios. In the first case (Fig. 2a), E2BS has chosen networks with less packet delay in 25% of the simulations, compared with 2.5% with SAW. Both methods selected the same network for 72.5% of the time. In comparison with TOPSIS, E2BS chose the best network for 42.5% of the time as opposed to 7.5% with TOPSIS. In 50% of the time, the same networks were selected by both methods. In the second case (Fig.2b) E2BS chose networks with higher available bandwidth in 22.5% of the simulations compared with 2.5% with SAW. Both methods chose the same network in 75% of the time. In comparison with TOPSIS, E2BS chose the best network for 35% of the time compared with 15% with TOPSIS. In 50% of the time, the same networks were selected by both methods.

A sensitivity analysis was conducted to verify if the chosen networks really have better quality among the others. Table III show the results for handover decision point 21 in VoIP application scenario. In this case, E2BS selected the best network compared to the other methods.

Table III: Sensitivity analysis for VoIP application scenario

Method	Packet Delay	Packet Jitter	Bandwidth	BER
E2BS	34.1ms	7.7ms	566kbps	10^{-4}
SAW	39.5ms	7.3ms	528kbps	10^{-3}
TOPSIS	80.4ms	5.7ms	501Kbps	10^{-2}

Table IV show the results for handover decision point 38 in video streaming application scenario.

Table IV: Sensitivity analysis for Video streaming application scenario

Method	Packet Delay	Packet Jitter	Bandwidth	BER
E2BS	76.9ms	7.4ms	49.4Mbps	10^{-4}
SAW	76.9ms	7.4ms	49.4Mbps	10^{-4}
TOPSIS	84.3ms	7.3ms	47.8Mbps	10^{-2}

In this case E2BS and SAW selected the same network while TOPSIS chose a network with worst packet delay and less available bandwitdh.

The results confirmed that E2BS is able to select a PoA with better access to application requirements by providing efficient quality-oriented mobility control decisions that meet the current wireless conditions of the PoA(s). It is thus, a suitable method to allow it to act as a handover decision mechanism whitin the innovative ETArch, and meet the current mobility control needs of this architecture.

V. Conclusion and Future Works

In this paper, we outlined E2BS, a decision control vertical handover mechanism which extends the Elitism Selection Strategy by combining MADM features to achieve efficient quality-oriented mobility control decisions. A preliminary evaluation was carried out in MATLAB, which confirmed that the capacity of the proposed solution was superior to that of the alternative methods currently available.

The next stage of this work is to integrate E2BS into ETArch mobility control mechanism and evaluate it at ETArch real testbed. The purpose of this is to access our mobility prediction model by session quality requirements and also estimate the benefits of the application perspective through different benchmarking.

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