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Feature Selection Methods for Imbalanced Classification Problems

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***Abstract*—Although it is widely accepted that the performance of classifiers is affected by imbalanced distributions, the role of feature selection in alleviating this issue has been less investigated in literature, most of the work focusing on high dimensionality datasets and ranker methods. This paper attempts to fill in a gap, by providing a theoretical survey of specific feature selection methods for imbalanced classification problems and a comparative analysis of the performance boost generated by different selection strategies for five different classifiers, on imbalanced problems that do not suffer from the high dimensionality issue. The results indicate that, in such scenarios, ranker methods do not generally produce performance improvements. The best feature selection strategy for performance improvement is still the wrapper methodology, which achieves a space reduction of about 40% and can also boost classification performance.**

I. Introduction

Classification in the presence of an imbalanced data distribution has emerged as a significant challenge in the data mining community in the recent years. Its increased popularity is proven by the numerous real-world problems facing this scenario on one side and papers, research groups and workshops focusing on this issue, on the other. But this interest has not been granted gratuitously: imbalanced data distributions are ubiquitous in data mining applications such as: text mining, fraud or intrusion detection, medical diagnosis, risk management, text classification and information retrieval, unexploded ordnance detection and mine detection [1], [24]. A classification problem is imbalanced if, in the available data, a certain class (the one of utmost interest in recognition) is represented by a very small number of instances compared to the other classes [15].

Imbalanced data distributions represent a challenge for most classification algorithms, since most traditional classifiers are affected by the class imbalance problem to some extent [15], [18], [21]. Also, the choice of the correct classification performance metric is a sensitive issue in such problems. A two-class imbalanced problem in generally described by the *Imbalance Ratio*, i.e. the ratio between majority(*negative)* and minority (*positive*) class instances [15]:

$$IR = \frac{n_{Maj}}{n_{min}} \tag{1}$$

Another relevant factor is the ratio between the problem dimensions, more specifically the ratio between the number of instances and the number of attributes (IAR)[18]:

$$IAR = \frac{n}{m}, \tag{2}$$

where n is the number of instances and m, the number of attributes.

A great deal of effort has been invested in developing classification mechanisms for coping with the data imbalance. The approaches can be divided in three categories:

- *data centered* strategies, which encompass various sampling approaches, both uninformed (random under- and over-sampling) and guided – the most prominent being the SMOTE (*Synthetic Minority Oversampling TEchnique*)[5] oversampling technique, with its many variations; the advantage of these methods is that they can be used as pre-processing steps, they are generally computationally efficient and algorithm independent; however, to maximize their effect, they should be paired with an appropriate learner, and most require significant additional effort in tuning the quantity of sampling required to achieve the best results
- *algorithm based* approaches, which focus on altering the inductive bias of classifiers, or devising specific strategies to adapt the general methodology for tackling the imbalance; while quite efficient in specific domains, such strategies are restricted to a specific classifier type
- *hybrid* approaches, which emerge as a result of the combination of sampling approaches with algorithm modifications, ensemble learning and/or cost-sensitive learning; while being the most intensive computationally, such approaches have proven to be quite efficient across a wide range of domains.

Significantly less effort has been directed towards studying the effect of general and specific (i.e. imbalance aware) feature selection methods on the classification performance in imbalanced problems. The current work focuses on providing a significant theoretical survey of specific feature selection methods for imbalanced classification problems, and a comparative empirical analysis of the efficiency of different selection strategies in improving the performance of various classifiers.

The rest of the paper is structured as follows: the next section briefly reviews the feature selection problem in general, and presents a survey of the most important techniques specific to imbalance scenarios. We attempt to provide a taxonomy of these techniques, as well as a brief discussion on performance metrics in imbalanced classification problems. Section III describes the experiments performed and presents a comparative analysis of different feature selection strategies in imbalance scenarios. The last section presents the concluding remarks.

Abdominal tumor recognition from ultrasound images using Complex Extended Textural Microstructure Co-occurrence Matrices

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Abstract—**Cancer is the one of the most frequent lethal diseases nowadays. The abdominal malignant tumors, such as the hepatocellular carcinoma and the colorectal tumors occur very often. The golden standard for cancer diagnosis is the biopsy, but it is invasive, dangerous. We develop non-invasive, computerized methods for tumor diagnosis, based on ultrasound images. In our previous research, we defined the imagistic textural model of the malignant tumors consisting of the most relevant textural features for the characterization of these tumors and of their specific values. Besides the classical methods for texture analysis, we previously developed and experimented superior order generalized co-occurrence matrices, based on gray levels, edge orientations and textural microstructures computed after applying the Laws convolution filters. In this paper, we defined the Complex Extended Textural Microstructure Co-occurrence Matrix (CETMCM) based on both Laws and edge features. We assessed the newly defined method through supervised classification techniques.**

Keywords— abdominal tumors, ultrasound images, imagistic textural model, Complex Extended Textural Microstructure Co-occurrence Matrix (CETMCM), classification performance.

I. INTRODUCTION

The hepatocellular carcinoma (HCC) is the most frequent malignant liver tumor, occurring in 70% of the liver cancer cases. It evolves from cirrhosis, after a phase of liver parenchyma restructuring, at the end of which sometimes dysplastic nodules result, which evolve into HCC [1], [2].

The colorectal tumors are abdominal malignant structures that frequently occur in the population of the developed countries. The most reliable method for cancer diagnosis is the needle biopsy, but this technique is invasive, dangerous, as it could lead to the spread of the tumor inside the body [3].

Our purpose is to develop non-invasive, computerized methods for the automatic and computer-aided diagnosis of these tumors, based on ultrasound images. Ultrasonography (US) is a reliable method for patient examination, being safe, non-invasive, inexpensive and repeatable. Other equivalent examination techniques, such as the computer tomography, the magnetic resonance imaging, the endoscopy, or the contrast enhanced ultrasonography, are irradiating or expensive.

Concerning the aspect of the considered tumors in ultrasound images, they usually have a hyperechogenic and heterogeneous aspect due to the presence of multiple tissue types (fibrosis, necrosis, fat cells and active growth tissues), as well as to the complex structure of vessels. However, it is difficult to distinguish these tumors within the ultrasound images, as the HCC tissue resembles the surrounding cirrhotic parenchyma and also the hemangioma benign tumor, while the colorectal tumors are similar in aspect with the Inflammatory Bowel Diseases (IBD). Some eloquent examples of B-mode ultrasound images representing these tumors and the IBD affections are provided in *Figure 1.*

Texture is an important concept in this context, putting into evidence subtle characteristics of the tissue, beyond the perception of the human eye.

The texture analysis methods, in combination with classifiers, have been widely implemented in the nowadays research, in order to perform the recognition of some severe diseases based on the information obtained from medical images [4], [5], [6], [7], [8], [9].

In our previous work, we defined the imagistic textural model the malignant tumors, consisting of the exhaustive set of relevant textural features that best characterize these tumors and of their specific values: arithmetic mean, standard deviation, probability distribution.

Concerning the texture analysis techniques, we previously implemented classical methods such as the first order statistics of the gray levels (arithmetic mean, maximum and minimum values), the autocorrelation index, the gray level co-occurrence matrix of order two and the associated Haralick features, edge based statistics, the frequency of the textural microstructures derived by using the Laws' filters,

A Neural Model for Semantic Oriented Aspect Based Opinion Mining

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*Abstract***—We present an approach for aspect based opinion mining, which uses an unsupervised neural network as the opinion classifier. The neural model is an extension of the Growing Hierarchical Self-organizing Maps. In our aspect based sentiment analysis method, we assume that different sentences in a product review refer to the different aspects of the reviewed product. We use the Growing Hierarchical Self-organizing Maps in order to classify the review sentences. This way we determine whether the various aspects of the target entity (e.g. a product) are opinionated with positive or negative sentiment in the review sentences. We classify the sentences against a domain specific tree-like ontological taxonomy of aspects and (positive/ negative) opinions associated with the aspects. As a consequence, we really classify the sentiment polarity about the different aspects of the target object, as expressed in the sentences. Moreover, being based on a classification against an ontology of aspects, our approach is semantic oriented, where the aspects themselves are also defined semantically. The approach proposed has been tested on a collection of product reviews, more exactly reviews about photo cameras.**

Keywords—sentiment analysis; unsupervised neural network; aspect/ opinion ontology

I. INTRODUCTION

Sentiment analysis, also known as opinion mining, is a research area that aims at extracting the opinions (i.e. sentiments) regarding a product, a service or a place, as expressed by people in online reviews. The sentiment analysis can be performed either at document level, at sentence level, or at aspect level. At the document level, opinion mining consists in identifying the overall sentiment polarity as expressed in a review as a whole. At the sentence level, sentiment analysis means identifying the opinion polarity expressed in each sentence of the review, while at the aspect level, the sentiment polarities about each of the different aspects of one target entity are identified.

In this paper we adopt an unsupervised machine learning method in order to do aspect based opinion mining. More concrete, our approach uses an unsupervised neural network as the sentiment classifier. The neural model is an extension of the Growing Hierarchical Self-organizing Maps. In our aspect based opinion mining method, we assume that different sentences in a product review refer to the different aspects of the target product. We use the Growing Hierarchical Self-organizing Maps (GHSOM) – actually, our extended variant, called Enrich-GHSOM – as a classifier for the review sentences. With this classification, we discover whether the various aspects of the target entity (e.g. a product) are opinionated with positive or negative sentiment in the sentences of a review. We classify the sentences against a domain specific tree-like ontological taxonomy that includes the aspects as well as the (positive/ negative) opinions associated with the aspects. This way, we really classify the sentiment polarity about the different aspects of the target object, as expressed in the sentences. Moreover, our approach is semantic oriented, as it is based on a classification against an ontology of aspects. The aspects themselves are also defined semantically.

In our aspect based opinion (sentiment) analysis approach, we discover the polarity of the opinion expressed in each text sentence about the only aspect mentioned in the sentence or about the most relevant of the multiple aspects mentioned together in the sentence, as in [3]. The target object is a product or a service, for instance a photo camera or a touristic resort. The aspects are the characteristic features (attributes) of the objects, for instance the lens, the image quality, the weight (for a camera), or a beach, a ski track, a waterfall (for a resort).

When analyzing the opinions expressed towards the different aspects, we use the bag of words to represent a sentence, without any part of speech restriction. Actually, the most important (relevant) words for our aspect level opinion classification are the nouns and the adjectives.

In our aspect based opinion mining method, for each sentence of an online review we discover the sentiment polarity as expressed in the sentence towards an aspect mentioned in the sentence. In the spirit of [2, 9], when classifying the opinion polarities, we speculate the structure of the hierarchical relations among the different aspects of a target object. This structure has not been utilized enough so far in the opinion mining literature. We represent this structure as a tree-like ontology. The ontology structure reflects a hierarchy of the aspects (features, attributes); in addition, every intermediate node (representing an aspect) has two leaf children representing a positive opinion polarity and a negative opinion polarity towards the aspect defined by their parent node. This way, we approach the opinion mining issue through a hierarchical classification process. In our approach, the hierarchical classification is performed by using the unsupervised neural network Enrich-GHSOM [8]. This neural network ensures the following behavior: based on the similarity between numeric attribute vectors, the vector representations of the text sentences propagate in a top-down manner, as starting from the root of the ontological structure of the target object; finally, each sentence halts on a leaf node, which always represents a (positive or negative) opinion polarity. This classification process is based on the similarity

Continuation Semantics for Maximal Parallelism and Imperative Programming

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***Abstract*—We present a denotational semantics for a simple concurrent imperative programming language in which the semantic operator for parallel composition is designed according to the maximal parallelism model of non-interleaved computations. The denotational semantics is designed with metric spaces and continuation semantics for concurrency. We also present a Haskell implementation of our denotational semantics in the form of a prototype interpreter.**

I. INTRODUCTION

In previous work we introduced a *continuation semantics for concurrency* (CSC) [15], [6] that can be used to model both sequential and parallel composition in interleaving semantics while providing the general advantages of the technique of continuations [14]. More recently, we investigated the possibility to express synchronization between two or multiple parties in continuation semantics [18], [7]; in [7], [18] we used CSC for this purpose. In [20] we used CSC in combination with classic continuation-passing style to express synchronization between multiple parallel components in a compositional manner.

In this paper we present a denotational semantics for a simple concurrent imperative programming language in which the semantic operator for parallel composition is designed according to the maximal parallelism model of non-interleaved computations. The denotational semantics is designed with metric spaces and continuations for concurrency following the approach introduced in [20]. We also present a Haskell implementation of our denotational semantics in the form of a prototype interpreter.

As it is well known, a number of mathematical theories have been developed based on models of the so-called *true concurrency* (or non-interlaving) kind. The notion of *Petri net* is of fundamental importance in this area. There is a well-known treatment of maximal parallelism in direct semantics; see, e.g., [2] section 15.2. In metric semantics the non-interleaving model was also investigated based on the *pomset* model [3]. Continuation-passing style was developed initially as a tool for denotational semantics [13], [12]. Our present aim is to show that the concept of maximal parallelism can also be expressed in continuation semantics.

A. Contribution

We show that the continuation-based technique introduced in [20] can be used to model *maximal parallelism* (sometimes called *synchronous parallelism*) in a compositional manner. In [7], [18] the semantics of synchronization is expressed by using silent steps or hiatons (see, e.g., [2], chapter 9), which are needed to achieve the contractiveness of some higher-order mappings. The technique introduced in [20] can be used to express synchronization between two or multiple parallel components without using silent steps or hiatons. We present a denotational model for maximal parallelism designed by using the continuation-based technique introduced in [20]. Our denotational (mathematical) semantics is given in Section IV. In Section V we also present a Haskell implementation of our denotational semantics in the form of a prototype interpreter for the language under investigation, that can be easily tested and evaluated.

II. PRELIMINARIES

The notation $(x \in)X$ introduces the set X with typical element x ranging over X. Let $f \in X \to Y$ be a function. The function $(f \mid x \mapsto y) : X \to Y$, is defined (for $x,x' \in X, y \in Y$) by: $(f \mid x \mapsto y)(x') =$ if $x'=x$ then y else $f(x')$. Instead of $((f \mid x_1 \mapsto y_1) \mid x_2 \mapsto y_2)$ we write $(f \mid x_1 \mapsto y_1 \mid x_2 \mapsto y_2)$. In general, instead of $((f \mid x_1 \mapsto y_1) \cdots \mid x_n \mapsto y_n)$ we write $(f \mid x_1 \mapsto y_1 \mid \cdots \mid x_n \mapsto y_n)$. If $f : X \to X$ and $f(x) = x$ we call x a *fixed point* of f. When this fixed point is unique (see Theorem 2.1) we write $x = fix(f)$.

A *multiset* is a generalization of a set. Intuitively, a multiset is a collection in which an element may occur more than once, or an unordered list. One can represent the concept of a multiset of elements of type A by using functions from $A \to \mathbb{N}$, or partial functions from $A \to \mathbb{N}^+$, where $\mathbb{N}^+ = \mathbb{N} \setminus \{0\}$ ($\mathbb{N}^+$ is the set of natural numbers without 0). Let $(a \in)A$ be a countable set. We use the notation:

$$[A] \stackrel{not.}{=} \bigcup_{X \in \mathcal{P}_{finite}(A)} \{m \mid m \in (X \to \mathbb{N}^+)\}$$

where $\mathcal{P}_{finite}(A)$ is the power set of all *finite* subsets of A. As A is countable, $\mathcal{P}_{finite}(A)$ is also countable. An element $m \in [A]$ is a (finite) multiset of elements of type A, a function $m : X \to \mathbb{N}^+$, for some finite subset $X \subseteq A$, such that $\forall a \in X : m(a) > 0$. $m(a)$ is called the *multiplicity* (number of occurrences) of a in m. $[A]$ is the set of all finite multisets of elements of type A.

One can define various operations on multisets $m_1, m_2 \in [A]$. Below, $\mathsf{dom}(\cdot)$ is the domain of function '·'. The *multiset sum* operation $\uplus : ([A] \times [A]) \to [A]$ can be defined as follows:

$$\mathsf{dom}(m_1 \uplus m_2) = \mathsf{dom}(m_1) \cup \mathsf{dom}(m_2)$$

Server-Triggered Trusted User Confirmation of Transactions Performed on Remote Sites

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***Abstract*—Users need to run their security-sensitive applications in a trusted environment. The trustworthy characteristics of such environments are built by imposing restrictions on the user applications' interface and functionality. We propose a method to let the users benefit from both an improved usage experience and a trusted environment. Our method applies the method of alternate usage of two separated virtual machines (VMs), i.e. a trustworthy green VM for security-sensitive applications and an untrusted red VM for the others, at the intra-application level: an application is separated in two phases (security-insensitive and security-sensitive, respectively) and only the later is run in the green VM. This way, the restricted usage time is reduced to the minimum needed. We exemplify on e-commerce applications that perform transactions on a remote service in two consecutive phases: (1) preparation and (2) confirmation. The protected application's execution is switched from the red into the green VM when its confirmation phase starts. Thus the server obtains a trusted user confirmation regarding the transactions prepared in the previous phase. The trusted confirmation is requested by the server, not the client. The server could even not require it at all, a decision taken based on risk analysis and security policies including user's preferences and behavior. We implemented our method on an open-source e-commerce application and estimated the performance improvements.**

***Keywords*—virtualization, red and green VM, trusted environment, two phases, trusted confirmation, optional VM switch**

I. Introduction

Users need to have their private valuable date protected when running applications that manipulate that data. Even supposing that such security-sensitive applications are trusted, protecting them when run in an untrusted environment (composed by the untrusted underlying OS, other applications and remote parties) proved to be a difficult task, due to the large attack surface of such systems.

A solution to this problem is to separate the user applications in two classes, i.e. security-sensitive and security-insensitive, respectively, and run them on different computers [1], [2]: the first class on a *trusted green machine* and the second one on an *untrusted red machine*. While maintaining two different physical machines could be difficult and inconvenient in practice, virtualization could be used to run instead two virtual machines (VM), i.e. the *green VM* and *red VM*, on the same physical system.

Beside the obvious advantage of consolidating more VMs on the same user physical system [3], virtualization also brings important benefits from the security point of view [4], [5], [6], [7]. The most important one in the red-green VM context is the isolation required between the two VMs. Assuming the virtualization software — i.e. the hypervisor (HV) — is free of vulnerabilities, isolation is as strong as the physical one. Virtualization could also be used to isolate the security tools from the protected system (i.e. by placing them outside the protected VM, in HV or another VM) and provide an improved control over the protected VM [8].

The trustworthy characteristics of the green VM are given by the fact that only trusted applications are run inside it and only trusted inputs are accepted. The later condition also means that the green VM communicates only with trusted remote parties. This results in a more accountable, so more trustworthy environment, though a very restricted one. Yet, the users also need the freedom to use untrusted applications and communicate with untrusted parties. Reconciling the two different needs, implies the usage of both VMs.

This be done in two ways: (*1*) *concurrently* [9] or (*2*) *alternatively* [10], [11]. While running the red and green VMs concurrently has the advantage of letting the users simultaneously use all their applications, it rises more technical challenges, among which safely sharing of the physical resources between the two VMs and provision of trusted I/O channels between the user and the green VM are the most difficult ones. The alternate usage, on the other hand, means that at one moment just one VM is active and running, while the other one is suspended. The active VM could be given direct access to the physical resources, making thus the HV much simpler and, consequently, safer [12]. This way, the resource sharing problem could be solved for stateless resources (e.g. CPUs, memory) by simply reinitializing them. The problem still remains for stateful resources like the HDD. There are solutions [11], [13] that allocate separate resources to the different VMs and others [14] that use a RAM-based disk for the green VM and the physical HDD for the red VM. The trusted I/O channel problem is completely solved, since all I/O devices are in control of just the active VM at one moment and their state could be reset before being used.

There are though some disadvantages of the course-grain red-green VM separation, like: the lack of interaction possibilities between the trusted and untrusted applications (even if apparently a contradiction, a needed feature in some cases), the usability restrictions for the applications in the green VM, the relatively large switch time between the two VMs in case of the alternate VM strategy. Besides, even if more trustworthy, the green VM is not completely free of vulnerabilities, due to its still relatively large trusted computing base (TCB), composed by its entire software stack (OS and applications). This is why other finer-grained approaches propose different kinds of separation and isolation. Some solutions like [15],

Performance analysis of routing optimization in Proxy Mobile IPv6 environments

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***Abstract*—Proxy Mobile IPv6 technology is able to provide mobility for users, without application-level interruptions. A test bench which allows for analyzing, developing and testing adaptive routing algorithms between Proxy Mobile IPv6 entities has already been proposed. The associated algorithms select the best path for each traffic class as a function of the parameters that affect application performance. The experimental results proved that using the proposed test bench, routes are changed dynamically depending on the performances of the Internet Service Providers. Also, it was obtained an increase in network throughput compared to dynamic routing. The present paper presents a deeper performance analysis of the proposed test bench compared to dynamic routing, considering different test scenarios and different types of traffic flows (TCP and UDP).**

Keywords*—Proxy Mobile IPv6; routing optimization; performance analysis

I. Introduction

With the ever-increasing Internet penetration and telecommuters working from virtual offices while on the move, the demand for continuous connectivity for user's applications, regardless of their location becomes higher and higher. Using Proxy Mobile IPv6 (PMIPv6) host devices are able to maintain their IPv6 address regardless of their location, thus allowing seamlessly support for application level communications, without interrupting the connections.

In high-speed IP networks, applications like audio conferences, video conferences, VoIP, video telephony, are becoming imperative demands in a technological dependent society. With this high increasing demand, a new technology emerged, generic called Quality of Services (QoS), which ensures that one less critical IP application (e.g. web browsing) does not interfere with another critical IP application (e.g. video conference). The service represents the traffic performance provided to the client and is characterized by the QoS parameters such as bandwidth, delay, jitter, availability or error rate. In order to ensure these parameters, the provider implements QoS using specific techniques.

It was proposed a test bench for routing optimization algorithms in Proxy Mobile IPv6 environments which select the best path between Proxy Mobile IPv6 entities function of QoS parameters like availability, delay, available bandwidth and required bandwidth. The routes are changed dynamically function of the measured performances of the Internet Service Providers and set independently for each traffic class. The main aim of this paper is to present a pertinent performance analysis of the proposed test bench, compared to the dynamic routing, considering different test scenarios and different types of traffic flows. Network communications rely on the transport layer protocols. These protocols provide different services and have different mechanisms for data transfer. Our analysis takes these differences into consideration and proposes a test scenario for each transport layer protocol. The experimental results proved major performance improvements when our proposed test bench for routing optimization was compared with dynamic routing. Also, as will be seen further, these improvements are different from one transport layer protocol to another.

The paper is organized as follows: Section II provides background information and theoretical considerations about Proxy Mobile IPv6 components and operations, Quality of Service, IPv6 routing technologies and IP transport-layer protocols. Section III presents the proposed test bench for routing optimizations in Proxy Mobile IPv6 environments. Section IV presents the experimental tests and results. Section V concludes the paper and discusses future research topics, in the context of Future Internet and mobile environments.

II. Theoretical Considerations

A. Proxy Mobile IPv6

Proxy Mobile IPv6 (PMIPv6) [1] provides network-based IP Mobility management to a Mobile Node (MN). PMIPv6 entities track the movements of the MN, initiate the mobility signaling, and set up the required routing state without requiring the participation of the MN in any IP mobility-related signaling.

Mobile Access Gateway (MAG) performs mobility-related signaling on behalf of the MN. It obtains an IP address from Local Mobility Anchor (LMA) and assigns it to MN, retains the IP address of the MN when the MN roams across MAGs and tunnels traffic from MN to LMA. Local Mobility Anchor is the home agent for MN, the topological anchor point for MN home network prefixes and manages the binding state of an MN in a Proxy Mobile IPv6 (PMIPv6) domain. It has the functional capabilities of a home agent as defined in the Mobile IPv6 base specification (RFC 3775) [2] along with the capabilities required for supporting the PMIPv6 protocol. PMIPv6 domain is the network where the mobility management of an MN is handled using PMIPv6 protocol. MN is an IP host whose mobility is managed by the network. MN's home address (MN-HoA) [3] is an address from MN's home network prefix (HNP). The MN is able to use this address as long as it is attached to the access network