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Access Selection and User Profiling in Reconfigurable Terminals

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Abstract—This paper presents a mobile terminal architecture for devices operating in heterogeneous environments, which incorporates intelligence for supporting mobility and roaming across legacy access networks, as well as dynamic user profiling. It defines and discusses two separate problems identified in this area, namely the Intelligent Access Selection (IAS) and the Modelling and Adaptation to User Preferences (MAUP) problems. It proposes solution approaches and presents indicative results in the context of real-life scenarios. The first problem relates to terminal-controlled access network selection in heterogeneous networks, while the second one involves the automatic determination of the user's preferences.

Index Terms— access selection, always best connected, optimization process, user preferences.

INTRODUCTION

THE evolution of wireless communication systems over the past years demonstrates a clear trend towards architectures that will support multiple access technologies and types of terminals, capable of alternatively operating in the diverse radio segments available in the infrastructure. These access technologies (WLANs, third-generation cellular systems, and broadcast networks, such as Digital Video Broadcasting) will thus constitute cooperating components of a composite radio infrastructure, interconnected by a backbone (e.g. an IP-based fixed network) and jointly operated in an optimized fashion that will allow for an improved overall resource management. This trend is often referred to as 'systems beyond 3G' or '4G wireless systems' and continues to attract notable research attention [1]–[4].

A central issue related to the above, is the design of suitable management frameworks, both for the terminal and for the network, which will allow for seamless service provision, independently of the network the user is attached to. Another important aspect is the fact that the user will need to control the usage of the available networks, especially when this usage comes with a price. This involves a potentially complex decision-making process, which may be guided by policy management tools, with support from both the user devices and the networks [5]–[7], thus giving rise to the cardinal issue of optimally distributing intelligence between the network and the mobile terminal, in order to support seamless mobility and service provisioning.

Another challenge that emerging communication systems are faced with involves the ability to trace and exploit a broad collection of data that characterize the so-called usage context. By context, we refer to any information related to user tasks and experience (including surrounding conditions, user preferences and profile, historical data and other) that by being available to the system for further processing can assist it in fulfilling its goals [8]–[10]. User mobility creates situations where the user's context is highly dynamic: interaction, execution and usage needs change frequently and rapidly. This implies that 4G management frameworks must also provide a way for services and terminal settings to adapt appropriately to this constantly changing environment [11]–[13].

Moreover, one of the main criteria that influence the terminal's access selection process, in an environment with multiple access technologies available, is the user's

preferences and profile, which may also be dependent on the usage context. For example, a user on a business trip may not consider cost to be an important issue in comparison to quality of service, but the same user may want to minimize cost in a leisure time situation [14],[15].

Hence, the goal in managing 4G systems proves to be twofold: not only does it lie in the seamless integration and the joint utilization of all the available technologies for the provision of higher data rates, but also in the exploitation of a variety of contextual data for the development of innovative, personalized services.

Accordingly, in the context of effectively managing wireless terminal operation in composite radio environments, two problems are identified: Intelligent Access Selection (IAS), which involves the computation of optimal allocations of services to access networks and to quality levels, given network availability and user preferences, and Modelling an Adaptation to User Preferences (MAUP), which involves, firstly, the processing and the 'decoding' of contextual information for the purpose of determining the usage context, and, secondly, the automatic determination of the user's preferences, according to the usage context and the set of services under investigation. This paper includes the formal definition and a potential solution to these problems. Their combined solution enables user terminals to be driven to allocations of services to access networks and quality levels which satisfy user preferences, in the order of priority specified by the usage context.

In this paper, we argue that appropriate functionality for handling the IAS and the MAUP problems must be in place at the mobile terminal, and for enabling it to handle basic mobility management tasks, to support the applications in dealing with the dynamics and heterogeneity of the available access networks and to dynamically adapt to changing user preferences. The work of this paper is generic with respect to the wireless technologies included in the composite radio infrastructure, and also generic with respect to the modelling of the context space. This work can be the basis for further research in the area of developing efficient algorithms for service configuration, as well as in the area of preference modelling and dynamic user profiling.

Requirements

The efficient exploitation of the composite radio infrastructure calls for the development of an appropriate, sophisticated Terminal Management System (TMS) that should be capable of: (a) detecting available access networks; (b) receiving and processing measurements regarding the capabilities of available attachment points; (c) accessing, modifying and storing the user profile; (d) allowing the user to dynamically redefine his preferences; (e) alternatively, the terminal may incorporate an appropriate mechanism for the automatic adaptation to the user's preferences, according to the identified usage context; (f) optimally selecting allocations of services to access networks and to quality levels; (g) supporting the applications in handing over the existing connections from one access network to another, in a seamless manner.

Terminal Management Architecture

Overview

The TMS must be modelled for a modern, general-purpose operating system, running on a mobile terminal that may be continuously switched on [16],[17]. Fig. 1 illustrates the main components of the TMS architecture, namely the Network Interface Adaptation Module (NIAM), the Mobility Management Module (MMM) and the User Preferences Module (UPM).

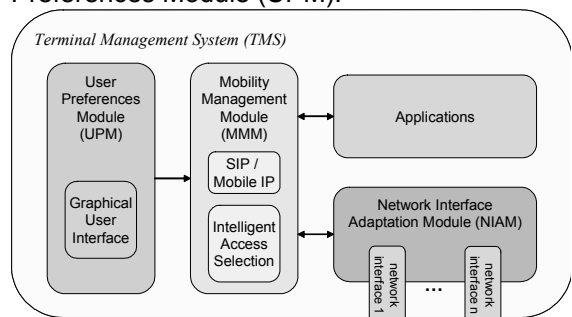


Fig. 1. TMS Architecture

Network Interface Adaptation Module (NIAM)

The NIAM is responsible for identifying the different interfaces present in the terminal, for monitoring their status, for collecting measurements from each interface and for executing the selection and de-selection of the appropriate interface. More specifically, the NIAM serves two purposes: (a) the connection and de-connection of the

appropriate interface during power-up of the mobile terminal or during a handover and (b) the retrieval of layer-2 measurements in the network interface. This means that the NIAM is able to provide the terminal with measurements retrieved from the different network drivers, reflecting the signal quality or connectivity status in each of these interfaces in an abstracted way (e.g. good, average or poor signal strength). In all, the NIAM will be able to provide the terminal with a list for each attachment point in the terminal's neighbourhood, each list comprising information about the attachment point's signal strength and bandwidth availability, its type of technology, its network operator and about the cost at which it is able to provide each available service at each of the service's permissible quality levels.

Mobility Management Module (MMM)

Overview

The MMM incorporates functionality for managing mobility both at the link layer (computation of optimal allocations to attachment points and quality levels, control for connection establishment and release at network interface level) and at higher levels (IP layer handoff transparency, application control). The first aspect of mobility management is provided for through the use of an algorithm that solves the IAS problem, while the second aspect may be provided for through the incorporation of appropriate protocol solutions, such as Mobile IP [18]-[21] and SIP [22]. That is, the assumption is made that the terminal implements the multihoming notion, the ability to simultaneously use multiple network interfaces, using different network addresses over each interface. These functions are presented in Fig. 2.

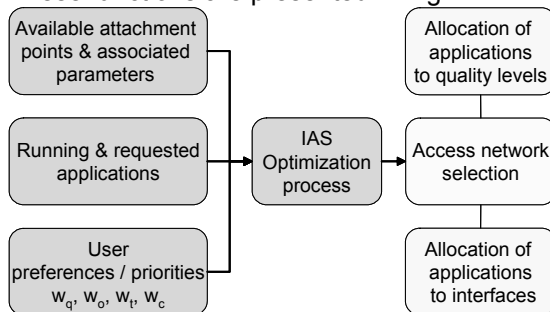


Fig. 2. Intelligent Access Selection optimization process

Intelligent Access Selection (IAS)

The input to the IAS problem falls in three categories: (a) a set of measurements, reflecting the capabilities of available

attachment points, as perceived by the mobile terminal. More specifically, these measurements comprise, for each available attachment point in the terminal's neighbourhood: (i) its availability in bandwidth, (ii) the signal strength perceived at the terminal from that point, (iii) the type of the technology that point supports, (iv) the network operator it belongs to, (v) its identifier, as well as the identifier of the terminal's network interface which communicates with that point; (b) the set of applications that are already running on the mobile terminal, the corresponding quality levels at which these applications are being provided as well as the set of applications that the user is requesting to use; (c) the set of user preferences, according to which the parameters 'quality', 'network operator', 'technology type' and 'cost' are prioritized.

The solution of the IAS problem is the result of an optimization process that should produce the following results: (a) an allocation of services belonging to the two aforementioned sets to quality levels; (b) an allocation of services belonging to these sets to attachment points. These allocations should optimize an objective function associated with the quality level and cost at which each service is provided, with the type of technology and the network operator through which this provision is effectuated, and with the importance the user allocates each of these factors, at a given time.

The constraints that the computed allocations have to satisfy fall in the following categories: (a) each service must be allocated to a permissible quality level; (b) the maximum quality level that the user defines for each service must not be violated; (c) the user's preferences must be taken into consideration in the order of priority that is specified in his profile.

The algorithm for solving the IAS should be triggered in the following cases: (a) whenever the user issues a service request; (b) whenever the user modifies his profile; (c) whenever serious signal degradation, or complete signal loss, from an attachment point the terminal is connected to is detected; (d) whenever a new available attachment point 'appears' in the terminal's neighbourhood, or an already available one 'disappears'.

User Preferences Module (UPM)

Overview

The UPM is responsible for storing,

accessing and editing the user's profile, and for addressing the MAUP problem. A system that considers usage context and service requirements shall provide appropriate prioritization of the parameters that may influence the access network selection process. This prioritization is equivalent to the specification of values for the different coefficients w_q , w_o , w_t and w_c , which correspond to parameters 'quality', preferred 'network operator', preferred 'technology type' and 'cost' respectively, and represent the measure by which each one of these parameters is weighted in the access network selection algorithm. For example, if the user chooses to specify that at a given moment 'quality' is for him the most important factor in access network selection, 'technology type' comes second, 'cost' comes third and last comes 'network operator', then the respective coefficients will be assigned values $w_q > w_t > w_c > w_o$.

Modelling and Adaptation to User Preferences (MAUP)

We propose an approach to the MAUP problem based on a system that models user preferences and the causal relationships between them using Bayesian meta-networks [14],[23],[24]. The goal of such a system is the prediction of the values of user preferences, every time the IAS function is initiated. This function presupposes the development of appropriate mechanisms through which: (a) the usage context will be inferred, given contextual information (user location, time and date, application type being used, terminal type being used, content type being accessed – e.g. web page with business data, phone call to a family member etc.); (b) the user preferences will be inferred, given usage context and service requests. These functions are depicted in Fig. 3.

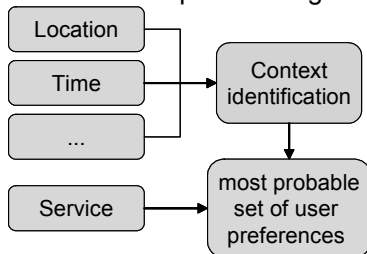


Fig. 3. Profile handling at the mobile terminal

More specifically, the construction of such a modelling system requires: (a) the development of an efficient algorithm for the inference of the usage context, based on the values of the contextual attributes (location, time etc) and the causal relationships

between them; (b) The development of an efficient algorithm for the inference of the values of target attributes (user's preferences w_q , w_o , w_t , w_c) based on the usage context and the causal relationships between predictive attributes (requested service, etc).

IAS Analysis

This subsection provides the formal description of the IAS problem.

Let $S = \{s_1, s_2, \dots, s_k\}$, $k \in \mathbb{N}$ be the set of both running and requested services at the mobile terminal, let $P = \{p_1, p_2, \dots, p_n\}$, $n \in \mathbb{N}$ be the set of attachment points that the terminal perceives and let $Q_s(p) = \{q_1, q_2, \dots, q_m\}$, $m \in \mathbb{N}$ be the set of quality levels at which attachment point p , $p \in P$, may offer service s , $s \in S$. The size of set $Q_{p,s}$ depends on both the bandwidth capabilities of point p and specific characteristics of service s .

We aim to compute allocations of services: (a) To quality levels: we denote this allocation as $A_{S-QL} = \{ql(s) \mid \forall s \in S\}$; (b) To attachment points: we denote this allocation as $A_{S-AP} = \{ap(s) \mid \forall s \in S\}$.

These allocations should optimize the objective function:

$$OF(A_{S-QL}, A_{S-AP}) = \max_{\forall s \in S} \left\{ \max_{\forall p \in P} \left\{ \max_{\forall q \in Q_{p,s}} \left\{ F(p, q, s) + OF(S - \{s\}, P') \right\} \right\} \right\} \quad (1)$$

where:

$$F(p, q, s) = w_q \cdot F_Q(p, q, s) + w_t \cdot F_T(p) + w_o \cdot F_o(p) - w_c \cdot F_c(p, q, s) \quad (2)$$

subject to:

$$ql(s) \leq ql_{s,max}, \forall s \in S \quad (3)$$

and $OF(\emptyset, P) = 0$.

Relation (1) expresses the objective of finding allocations A_{S-QL} and A_{S-AP} that optimize an objective function, associated with the satisfaction of user preferences, in the order that these are specified in his profile, while relation (3) ensures that the user's constraint regarding the maximum allowed quality level for each service will be respected.

Coefficients w_q , w_o , w_t , w_c correspond to the user's preference for (high) quality, a specific network operator, a type of technology and (low) cost respectively.

Factor $F_Q(p, q, s)$ expresses the quality level at which attachment point p offers service s , and is a function both of attachment point's p available bandwidth ($BW_{Av}(p)$), but also of the perceived signal strength from point p . Factor $F_C(p, q, s)$ expresses the cost at which point p offers service s at quality level q .

Factors $F_T(p)$ and $F_O(p)$ correspond to the network operator and the type of technology that characterize point p . In case the candidate attachment point p belongs to the preferred operator and/or supports the preferred technology, it is granted a 'bonus', whose value is proportional to the difference:

$$F_Q(p, q, s) - F_C(p, q, s)$$

Set P' differs in comparison to set P in that element p has been substituted by p' , the available bandwidth of which is lower, according to:

$$BW_{Av}(p') = BW_{Av}(p) - BW(s, q) \quad (4)$$

where function $BW(s, q)$ corresponds to the bandwidth that is allocated to service s at quality level q .

MAUP Analysis

We propose the construction of a two-level Bayesian meta-network (based on an approach presented in [14]) (Fig. 1), where the division of the MAUP problem in – initially – two separate stages is apparent: first, inference of usage context and, second, inference of user profile parameters.

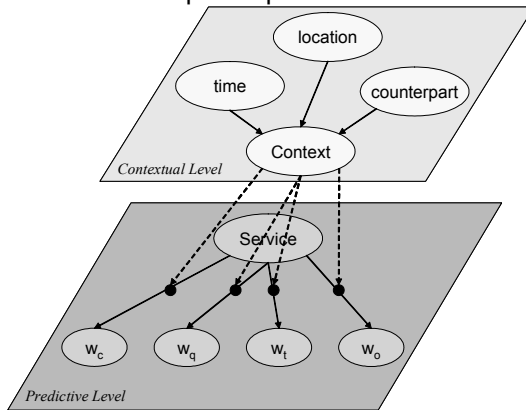


Fig. 4. A Bayesian meta-network for modelling user preferences

This structure assumes that the interoperability between the component

networks (on the contextual and predictive levels) can also be modelled by another Bayesian network. Thus, probability distributions associated with nodes on the predictive level depend on probability distributions associated with nodes on the contextual level.

In the proposed implementation, the MAUP problem is dealt with in three separate stages:

Stage 1: Inference of usage context. The Bayesian network of the second level (contextual level - Fig. 4) consists of four nodes. Each node represents a random variable. The values of random variables 'location', 'time' and 'communicating counterpart', the knowledge of the respective conditional probability distributions and the application of basic Bayesian inference rules lead to the determination of the most probable value for the random variable 'context'. This is accomplished with the construction of suitable conditional probability tables (CPTs), through which the computation of the maximum value of the conditional probability

$$P(C_i | T_j, L_k, CP_l), \forall i, j, k, l \in \square$$

and consequently of the most probable values for variable 'context' - C , given the values of variables 'time' - T , 'location' - L and 'communicating counterpart' - CP , will be achieved.

Stage 2: Inference of profile parameters. The Bayesian network of the first level (predictive level - Fig. 4) consists of five nodes: one for service (predictive attribute) and four more, one for each of the coefficients w_q , w_o , w_t and w_c (target attributes). The value of random variable 'context', defined following reasoning on the second level of the Bayesian meta-network, influences the way in which the values of w_q , w_o , w_t , w_c depend on the value of variable 'service' - S . Knowledge of the respective conditional probability distributions and the application of basic Bayesian inference rules leads to the determination of the most probable values of w_i . That is, the goal in this stage of the MAUP problem solution is the computation of the maximum value of the joint conditional probability

$$P(w_q, w_c, w_t, w_o | S)$$

given also the usage context. This is accomplished with the construction of suitable conditional probability tables (CPTs) for nodes w_q , w_o , w_t and w_c .

Stage 3: Learning and adaptation. The values of w_q , w_o , w_t and w_c that are computed, following reasoning on the first level of the Bayesian meta-network, are used in turn as input to the IAS problem. The decision (allocation) that is reached based on this input may or may not satisfy the user's needs, given the fact that his preferences were automatically defined, without his interference. Therefore, the ultimate goal is the training of the proposed network, in order to render it capable of accurately and independently predicting the user's preferences. This implies the development of an appropriate algorithm for the adjustment of the CPTs, according to the system's initial success or failure in accurately predicting the values of w_q , w_o , w_t and w_c .

This process involves the use of an appropriate training set, provided to the system by the user and comprising examples of his priorities in some situations. Our goal, therefore, is to extract knowledge about user preferences in any context, given his preferences in some instances of context.

In this paper, we propose the construction of a probabilistic neural network that uses the training set as a reference for the appropriate adjustment of the values stored in the Bayesian network's CPTs. This process is depicted in Fig. 5.

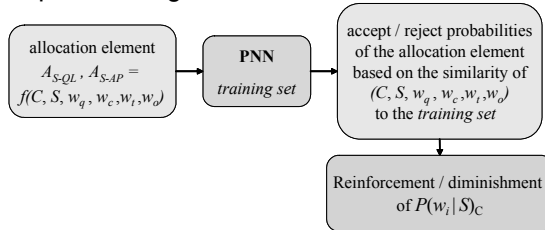


Fig. 5. Use of a neural network for the training of the system

The probabilistic neural network (PNN) receives as input a new allocation element computed by the system: given $C = C_i$ and $S = S_j$ and for $w_q = a_1$, $w_o = a_2$, $w_t = a_3$, $w_c = a_4$ designated by the solution of the Bayesian network, it performs the following tasks: (a). It assesses the similarity of the new instance ($C = C_i$, $S = S_j$, $w_q = a_1$, $w_o = a_2$, $w_t = a_3$, $w_c = a_4$) to the patterns stored in the training set (pattern layer neurons functionality); (b) It produces a probability vector, comprising classification probabilities to each class: $k_1 = 'accept'$, $k_2 = 'reject'$ (summation layer neurons functionality); (c) It selects the maximum of

these probabilities, using the Bayes-optimal decision rule (output layer neuron functionality).

Implementation and Evaluation

The TMS discussed in this paper has been implemented as a Java application, targeted either for Sun's J2SE Virtual Machine v1.2 (or later) or for J2ME Wireless Toolkit v2.2. The scenario presented here simulates a typical day in the life of a businessman, Mr. Green.

We consider two usage contexts (business and leisure) and three services (voice call, video streaming and web browsing). A high-level description of Mr. Green's preferences is given in Table I. The user has specified 'Oper#1' as his preferred operator and WLAN as his preferred technology for video streaming and voice call. The lowest quality level for each of the above-mentioned services is level '1', while the highest one is level '5'.

TABLE I. USER PREFERENCES (IMPLICIT)

	Leisure context (L)	Business context (B)
General Preferences	cost is more important than quality	quality is more important than cost
Voice Call (VC)	-	-
Video Streaming (VS)	technology is more important than operator	operator is more important than 'technology'
Web Browsing (WB)	technology is more important than operator	operator is more important than technology

On the basis of these preferences, the user provides the following 'accept' or 'reject' answers to several configurations of w_q , w_o , w_t , w_c , for each service and type of context (Table II).

TABLE II. USER'S ANSWERS TO RANDOMLY SELECTED QUESTIONS

Cxt	Srv	Accept				Reject			
		Q	C	O	T	Q	C	O	T
L	VC	4	1	3	2	1	4	2	3
	VS	4	1	2	3	2	4	1	3
	WB	4	2	3	1	1	3	4	2
B	VC	1	4	2	3	4	1	2	3
	VS	2	4	1	3	3	1	4	2
	WB	3	4	1	2	4	1	2	3

Thus, the user answers one pair of questions for each available service. The first question (configuration) of each pair is

randomly generated, while the second one is appropriately selected so as to significantly differ from the first one. We also note that ‘Q’ stands for quality, ‘C’ for cost, ‘O’ for operator and ‘T’ for technology, and that coefficients w_q , w_o , w_t and w_c are assigned values 0.8, 0.6, 0.4 and 0.2, according to their prioritization as first, second, third and fourth.

These answers constitute the training set, based on which the system is trained to accurately and independently predict the user’s preferences. It should be noted that we assume Mr. Green to be an average user, without any specific knowledge of the factors he is trying to prioritize. Thus, it is possible that Mr. Green answers a question incorrectly (with respect to the underlying preferences initially considered), or gives contradictory answers. The system tries to smooth out these contradictions and determine what the user actually has in mind, and is still able to predict the user’s preferences, even if he accepts or rejects both of the proposed configurations, or even if he provides answers for less than two questions per service and per context.

In the following, every step of the scenario, along with the corresponding allocations of services to networks and quality levels, are described in more detail. Moreover, in the third step of the scenario, the proposed solution to the MAUP problem is compared to a solution based on a simple rule-based system. Fig. 6 illustrates network coverage in each step of the scenario. For every available attachment point, its access technology, network operator, signal strength and available bandwidth are indicated.

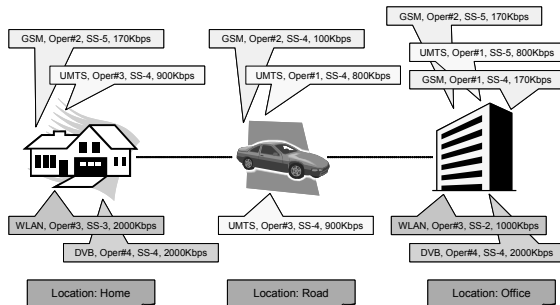


Fig. 6. Network coverage in scenario

(a) Morning, at home

Mr. Green is getting ready to go to work. He initiates a web browsing service and visits a sport news web site.

TABLE III. ALLOCATION SELECTED IN PHASE (A)

Srv	Cxt	Prioritization				Allocation		
		Q	C	O	T	Tec	Op	QoS
WB	L	4	2	3	1	WLAN	#3	1

At first, the TMS determines the usage

context. Based on current location (home), time (morning) and communicating counterpart (sports web page), context is defined as ‘leisure’. Then, the system successfully predicts Mr. Green’s preferences for the specified context and service. ‘Cost’ is deemed more important than ‘quality’, and ‘technology’ more important than ‘operator’. Thus, the WLAN access point is selected in this case, in combination with the lowest quality level, as this is the most cost-effective solution. This decision is also reinforced by the fact that WLAN is the preferred technology type.

(b) Morning, en route to work

Mr. Green is now on his way to his office. As he is running a little late, he decides to make a voice call to one of his colleagues at work.

TABLE IV. ALLOCATION SELECTED IN PHASE (B)

Srv	Cxt	Prioritization				Allocation		
		Q	C	O	T	Tec	Op	QoS
VC	B	1	4	3	2	UMTS	#1	5

The usage context type is now ‘business’ and thus ‘quality’ is more important than ‘cost’. Consequently, a UMTS access point and quality level ‘5’ are selected. The selected access point belongs to the preferred operator.

(c) Noon, at work

While at work, Mr. Green initiates a video streaming service, in order to have a video conference with his supervisor. After terminating this service, he makes a voice call to his wife, and also visits a music web site (web browsing).

TABLE V. ALLOCATION SELECTED IN PHASE (C)

Srv	Cxt	Prioritization				Allocation		
		Q	C	O	T	Tec	Op	QoS
VS	B	2	4	1	3	DVB	#4	5
VC	L	4	1	3	2	WLAN	#3	1
WB	L	4	2	3	1	WLAN	#3	1

For video streaming, the DVB access point is selected, as it is able to provide the maximum quality level, due to its high available bandwidth. This attachment point is also characterized by strong signal. On the other hand, voice call and web browsing are allocated to the WLAN access point and delivered at the minimum quality level, as their usage context use is defined as ‘leisure’.

It should be noted at this point that the user’s preferences where web browsing in leisure context is concerned, have already been determined in phase (a), so there is no need for re-evaluation, as they have already been cached. The system’s ability to cache already determined user preferences for a particular service and context further reduces

the terminal's computational load.

(d) Evening, at home

When Mr. Green returns home, he connects to the company's web site to download a financial report.

TABLE VI. ALLOCATION SELECTED IN PHASE (D)

Srv	Cxt	Prioritization				Allocation		
		Q	C	O	T	Tec	Op	QoS
WB	B	3	4	1	2	WLAN	#3	5

Web browsing is allocated to the WLAN access point and to the maximum quality level, as its usage context is 'business'. The WLAN access point is able to provide the maximum quality level. The decision is also reinforced by the fact that WLAN is the preferred access technology.

In comparison with a rule-based system, the proposed 'Bayesian' approach presents significant advantages. Let us assume that the terminal's manufacturer has integrated the following rules to the TMS:

When in 'leisure' context, let $w_c = 0.8$ and let all other factors be weighted equally, i.e. $w_q = w_o = w_t = 0.4$.

When in 'business' context, let $w_q = 0.8$ and let all other factors be weighted equally, i.e. $w_c = w_o = w_t = 0.4$.

Simulating phase (c) of the scenario using the above-mentioned rules would result in the allocations given in Table VII.

TABLE VII. ALLOCATIONS SELECTED BY A RULE-BASED SYSTEM FOR PHASE (C)

Srv	Cxt	Allocation		
		Tec	Op	QoS
VS	B	DVB	#4	5
VC	L	GSM	#2	5
WB	L	WLAN	#3	3

As can be observed, only the first allocation is the same compared to the 'Bayesian' approach. The other two are different, and apparently do not truly satisfy the user's preferences. Voice call is allocated to a GSM access point and to quality level 5, although a more cost-effective solution is appropriate. The same applies for the allocation of web browsing to a WLAN access point at quality level 3, as a lower quality level should have been chosen.

In general, our approach to the MAUP problem is more 'sensitive' and effective than a simple rule-based solution, without entailing any severe computational load. Furthermore, the use of a rule-based system presents the following significant drawbacks:

(a) It is not as adaptable and extendible. If the rules are integrated to the TMS by the manufacturers, then the users would not be able to edit them according to their own

needs and preferences. Even if the manufacturers allowed the modification of these rules, it would be too complicated for an average user to successfully personalize this set of rules. On the other hand, the proposed 'Bayesian' system can easily be trained, requiring the user to just answer a few questions.

(b) A rule-based approach cannot entirely satisfy the needs of a non-average user. For example, a user should be able to define more than two different context types. What is more, a complex personal profile would require a very complicated set of rules. On the other hand, all these requirements can be easily handled by the proposed system.

(c) A contradictory or false rule would result in allocations that do not correspond to the user's true preferences. In contrast, the proposed approach attempts to smooth out contradictory answers, in order to optimize the allocation decisions.

Conclusions

This paper identified and elaborated on two separate problems, in the domain of wireless terminal operation within fourth-generation, heterogeneous networks. These problems, the IAS and the MAUP, were defined, mathematically formulated and solved. Results were presented, in the context of a real-life scenario simulating the day of an ordinary user. These results were also compared with an alternative approach to the MAUP problem, involving the use of a simple rule-based system that emulates a user's reasoning where his preferences are concerned.

Directions for extending our work can be the following: (a) the development of alternative heuristic algorithms for the solution of the IAS problem, (b) the expansion of features taken into account by both problems, and (c) the development of an efficient algorithm for learning the structure of the Bayesian network used for modelling user preferences.

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