Selecting Access Network for BYOD Enterprises with Business Context (eBC) and Enterprise-Centric ANDSF

Rebecca Copeland and Noel Crespi

Rebecca.copeland@coreviewpoint.com, noel.crespi@it-sudparis.eu

Abstract. enterprises that adopt BYOD (Bring Your Own Device) need to optimize network selection for refundable employees' business usage. They can 'force-on-net' business sessions when employees are on-site and seek 'best connection' when employees are off-site, perhaps via hospitality partners that provide WiFi connectivity. For non-fundable, unproductive personal usage, service requests should be 'forced-off-net' and deferred back to the personal carriers. To achieve this, we propose that the Enterprise decides whether to accept or change the originating access network, having established the funding status via the eBC (enterprise Business Context) model. For each service request, the Enterprise evaluates QoE and Affordability vectors that are derived from prioritized STANDS and CART factors respectively and the results are used to select the optimal access network. An enterprise Access Discovery and Selection Function (eANDSF) is proposed to enable recommending preferred corporate hospitality partners to employees, instead of the carrier's list.

Keywords: ANDSF, BYOD, Always-Best-Connected, ABC, QoS, QoE, Context, MVNO, Hospitality, MOS, WiFi, WLAN.

1 Introduction

Selecting an access network for Mobile Broadband Data is the first frontier in establishing what services are selected for both Data services and Voice. Enterprises have long tried to persuade employees when they are on-site to use internal network resources instead of Mobile carrier's expensive services. The need to select affordable best connection is even more urgent for enterprises adopting consumerization, or BYOD (Bring Your Own Device), which is a trend sweeping the developed world [1]. BYOD means that personal devices are used for both business and private purposes and business usage is mixed with personal, yet legitimate business communication expenses still need to be refunded. Therefore, these enterprises need to optimize access selection to save costs of those sessions that are deemed refundable, whether on-site or off-site. They will save considerable costs when using spare capacity on their eWLAN for business usage. Enterprises also need to protect their own network from excessive personal use by employees and defer such service requests to the user's own carrier network, to be served and charged by the carrier. By doing so, enterprises will make better resources use and avoid unnecessary network upgrades.

C. Borcea et al. (Eds.): MobilWare 2012, LNICST 65, pp. 221–235, 2012.

Defining the best network connection is different when seen from the point of view of the carrier or that of the Enterprise. In most cases, carriers optimize across technologies (WLAN, UMTS, LTE) within their own network. The Enterprise's need of optimization is driven by the desire to minimize communications expenditure while providing QoE (Quality of Experience), reliability and security.

Researching cost models and charging levels is hard as information is not easily available and is often deemed private. The difficulty of defining what is 'best connection' was highlighted in [7], listing issues with the range of different technologies, compatibilities of terminals and radio networks, range of applications with different selection criteria and the many ways of measuring user satisfaction.

Beyond network optimization, most research papers looking at 'best connection' address the open WiFi access market. Hospitality establishments, such as café and hotel chains, are becoming aware that offering good connectivity attracts high-spending consumers to their premises. They may offer bulk discounts to enterprises that direct their employees to use preferred partner lists, where secure WiFi is offered, perhaps as part of the corporate rates of hotel rooms or business lunches.

In this paper we examine access selection for the Enterprise market. We suggest that the Enterprise uses the output from the previously proposed eBC function to determine what access network should be used. We also propose that the Enterprise maintains an enterprise-centric ANDSF and conveys its preferred lists to the devices. The paper includes related work and research in part II; in part III analysis of stakeholders motives and selection criteria; in part IV a description of the proposed enterprise ANDSF-eBC solution; in part V the decision process logic and call flows for handover between access networks; in part VI computing QoE and Affordability vectors from the STANDS and CART factors; in part VII illustrating cost savings and in part VIII – the conclusions.

2 Related Work

The proposed solution in this paper is based on the previously proposed enterprise Business Context (eBC) policy and the 3GPP ANDSF standards. The eBC has been developed particularly for enterprises that embrace BYOD. It enables differentiating business usage service requests from personal, so that business requests can be funded by the Enterprise, while personal requests are handles under the user's own subscription. In this paper we propose a new application utilizing the same eBC model – enterprise-centric access network selection, directing on-site business sessions to the eWLAN (enterprise WLAN) and personal sessions to the mobile carrier. The eBC policy concept has been introduced in [16]; requests detection and mapping to PCC (Policy & Charging Control) rules are proposed in [17]; the eBC platform and logic in [18]; and the computational model in [19].

ANDSF is the 3GPP standard mechanism of informing user devices of available access networks within range (see [11] and [15]). It allows carriers to convey access selection preferences to the device. ANDSF information is relayed between the network and the device over the 3GPP standard S14 interface. The protocol is based on the OMA (Open Mobile Alliance) Device Management (DM) function for a special ANDSF Management Object, using a SyncML- a sub-set of XML that is defined for it. The device communication with the provisioning server is secured by authentication with a 'stateful' dialogue, to prevent tampering.

In [12], a Prototype is described which simulates ANDSF in EPC (Evolved Packet Core). It demonstrates the use of ANDSF mobility rules, transferring from a trusted non-3GPP access gateway to an untrusted non-3GPP ePDG (evolved Packet Data Gateway) when connecting to 3rd party hotspots. In [6] and [7], Issues are raised regarding access discovery via broadcasting WiFi beacons, including high power consumption of always-on searching, user price privacy, price-QoS variations etc.

There is extensive research into Always Best Connect (ABC) methods. ABC has captured researchers' imagination, but implementations are hampered by both technical and business difficulties. The concept is often limited to network optimization, where carriers look for the most efficient transport of large volumes of data, as in the example of [3], with the proposed 'LessDamage' algorithm that needs no a priori traffic data. In [2], still from the carrier's perspective, the ABC algorithm combines network-context and user-device context, where 'user utility' is achieved via resource allocation through the mathematical 'knapsack' (or 'bin packing') problem. Addressing the consumer needs in [4], a discovery method of local access networks is proposed via a client that captures advertised service data (in this case, for video broadcast carriers) and filters it to present 'always best connected and best served' (ABC&S) recommendations. In [22], the complexity of defining ABC is discussed, where calculating user-centric options from price packages is declared as a '*combinatorial optimization problem*' that is 'NP-hard' and cannot be computed within a reasonable time. We have to concur with these findings.

While selecting best connection for network traffic optimization can be evaluated by objective, computational means, it is harder to assess the best connection by user satisfaction or QoE. Achieving high QoE is not just a function of the access network performance, but also all transport networks that are involved in the delivery. Measuring QoE relies on human perception of the delivered service, often captured by MOS (Mean Opinion Score). Various research papers attempted to quantify QoE, as in [14], which found a non-linear relationship with increasing network bandwidth, i.e. just adding capacity will not automatically increase user satisfaction. More recently in [21], an 'exponential relationship' by logarithmic computation of QoE values (in contrast with achieved QoS measurements) is proposed, where the QoE is presented as a distribution of logged MOS. This is still based only on generic QoS problems (loss, delay, jitter, reordering or throughput limitations) that appear to users as QoE problems (glitches, artifacts, pixilation or excessive waiting times).

There is little or no research on optimizing costs, yet user decisions are often swayed by affordability more than by quality. In [5], a user-centric approach is confused with device based approach, which is still under the carrier's control. Dealing with pricing issues is summarily dismissed '*because of flat rates*'. In fact, subscription fees bundle usage costs up to a threshold, with additional costs levied when exceeded, and this occurs more frequently with the advent of video services.

Context based decision-making methods have been researched by many disciplines, not just Telecom. In [20], context quality is aided by modified WPM (Weighted Product Method), where context attribute values are processed by MADM (Multi Attribute Decision Making) that employs fuzzy logic to achieve deterministic values. For mobile operators seeking best connectivity for roaming subscribers, several computed methods are described in [10], comparing mathematic models such as SAW (Simple Additive Weighting) as well as WPM. Other popular computational methods are based on TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and AHP (Analytic Hierarchy Process), as described in [8].

3 Access Selection Criteria

The issue of access selection is not merely having enough resources, but also having the right resources for the particular service, i.e. achieving QoE, not just improved QoS. In fact, users are far more influenced by pricing than QoE. The subjective view of the level of charges defines an 'Affordability' vector. It can be said that Affordability is to charging as QoE is to QoS - adding the human perception perspective. Neither Affordability nor QoE are absolute determinants without context, e.g. attitudes to a high price may be changed if the expense is refundable or the communication service is especially urgent.

Affordability and QoE present a conundrum: satisfaction is raised with better quality - this requires more resources and higher infrastructure cost - so charges are raised - but this leads to lower satisfaction - and raising satisfaction needs higher resources, and so on. In reality, this is solved by adding the dimension of context. This problem may be resolved by using the TOPSIS method [8] that identifies the option that has the shortest distance from the positive ideal solution and the farthest distance from the negative worst solution. However, using the TOPSIS method still needs separate handling of the QoE and the Affordability vectors, as we propose here.

The enterprise acts as an access provider when its employees are on the premises and as an access consumer ('buying' network resources from carriers and hospitality agents) when the employees are out of range. As an access provider, the Enterprise must curb excessive use, especially for unproductive personal usage, which could be charged to users' personal accounts, perhaps under their flat rate regime. As an access consumer, the enterprise needs to minimize refundable expenses by connecting to the lowest cost service with acceptable QoE and Affordability, and also ensure that business services are delivered at appropriate level of security. This means that the Enterprise should 'force' on-site business service requests onto the eWLAN and force unproductive personal usage out of the eWLAN. For personal usage, this means that the Enterprise policy may reject eWLAN requests and re-route to the user's own carrier, who will then decide whether to serve it on its 3G/4G network or to offload it to WiFi. When employees are off the premises, the Enterprise can select best partnering hospitality services, if they are better options than the carrier's offer.

To execute this enterprise-centric access selection, the enterprise first needs to obtain the context for the service request via the eBC Model [19]. In this paper, we propose to use the same eBC model (with prioritized STANDS factors) to determine the QoE vector and to use the CART factors, which are derived from employees' profile data, to generate the Affordability vector. Using both vectors, decisions can be made for business requests to be 'forced-on-net' and personal requests 'forced-off-net' when on-site, and use carrier's 3G/4G or hospitality WiFi when off-site. Additionally, enterprise-centric preferred lists of hospitality agents can be forwarded to the device when off-site. By optimizing session costs and maximizing utilization of existing internal capacity, considerable savings can be made.

4 Proposing eBC - eANDSF Solution

For best effect, BYOD enterprises should become MVNOs [17]. This allows the Enterprise to determine session policies and convey them to carriers, using the S9 standard interfaces, as defined in 3GPP [11]. Enterprises can also use eBC Policy when they have no MVNO status, but a Sponsor agreement instead. The Sponsor's particulars and the authorized service details are transferred via the Rx interface, which allows some, but not all, session parameters to be set by the Enterprise.

As an MVNO, the Enterprise acts like a 'home' network for the BYOD user's access via 3G/4G and can select access network. Service requests that are deemed as 'sponsored' will also reach the enterprise. However, not all WiFi/Internet sessions will be forwarded. Detecting and intercepting such requests are discussed in [17]. Figure 1 shows service request flows between the Enterprise and the access network providers. Business service requests (1, 2, 3) and personal requests (4, 5) can reach the Enterprise from its own eWLAN, from hospitality access or from the user's chosen carrier. The initial requesting access networks may or may not be the best choice for the Enterprise, in which case the Enterprise can instruct the employee's device to change it.

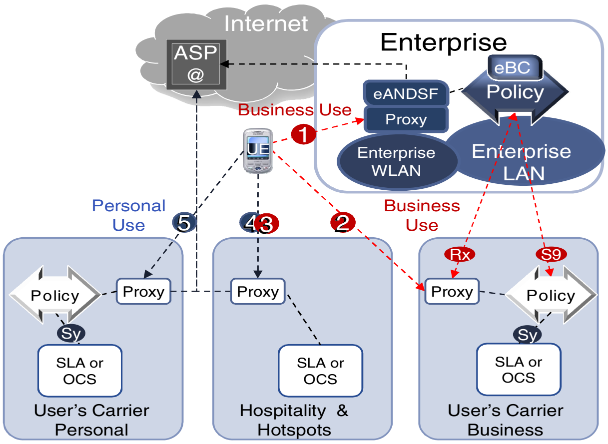

Fig. 1. Access for BYOD users in Business/Personal mode

The general access discovery process by beacon broadcasting is successful because no prior data needs to be provided, but it involves many issues, including excessive power consumption (due to constantly polling), pricing privacy and complex QoS/Policy packages. Hence, downloading coverage lists as a discovery method is deemed superior by [6], which proposes both terminal-based method (pull information continuously) and network-based method (server push, using location-based services). WiFi beacons enable local connectivity without a formal association with the device, a feature that can be exploited by local businesses for distributing coupons and promotions, as proposed by [13]. This can be a nuisance, and has inspired a contra proposal in [4] to discard such unsolicited broadcast data while collating local intelligence into more useful recommended lists.

3GPP defines ANDSF as an advisory service only, allowing configuration by local setting (device/user), home networks (MVNO/enterprise) or visiting networks (the user's carrier). Usually, device clients contain three WLAN lists: discovered un-prioritized advertised list, user/device preferred list and Carrier's (user's network) list. The enterprise can use the second list type and the device will be configured to prefer the Enterprise ANDSF as first choice. As shown in Figure 2, the mobile handset may connect to hotspots, carriers' WiMAX, UMTS, LTE and WLAN, and to Enterprise WLAN, and more than one ANDSF may be available for the device to download.

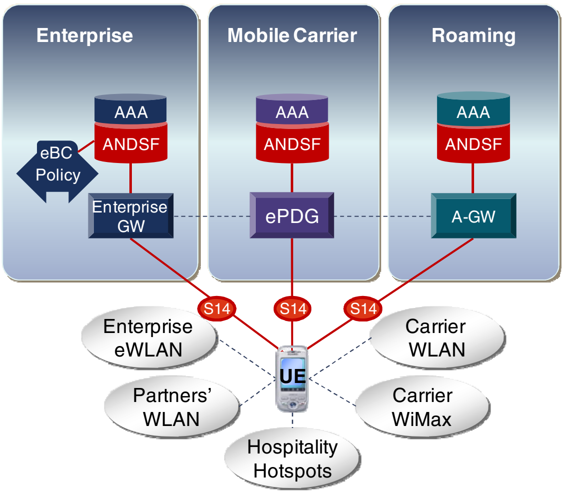

Fig. 2. Enterprise ANDSF as well as Carrier ANDSF

The ANDSF procedure is intended for carriers to assist devices in finding and connecting to their networks and their roaming partners. However, the 3GPP specifications [15], which support non-3GPP networks as well, are designed to support 'open', heterogeneous network environment, rather than dictate carriers' own selection. Hence, the concept of enterprises maintaining their own ANDSF should not be considered controversial. In providing an enterprise-centric ANDSF, the Enterprise can enforce its own access selection policies, direct employees to partners who provide discounted connectivity but also the required business quality and security.

Unlike WiFi beacons that anyone can tune to, the ANDSF information is confidential and specific. The information includes rules of selection, prioritized list of preferred networks in the vicinity and pricing details. This can be extended in the eANDSF to include enterprise-negotiated rates and historical evaluations of past QoE and affordability, thus providing meaningful selection information.

Using ANDSF is also safer – information is exchanged only when a secure connection is established, protecting devices from potential fraud and phishing. Another advantage is the unintended benefit of providing geo-location to the ANDSF server. In [12], this is highlighted as means of obtaining accurate geo-location for applications. This location data can also be used to determine the Spatial Factor for the eBC status, where the user's location is an important consideration.

5 The Access Selection Decision Process

The eBC evaluation score is the main input into the access selection process that determines a 'business' or a 'personal' service request. Another input is the request's original access – mobile carrier, enterprise internal network or hospitality WiFi. These aspects are analyzed in the logic flow as shown in Figure 3, which considers the two main scenarios - eWLAN generated and 3G/4G generated requests.

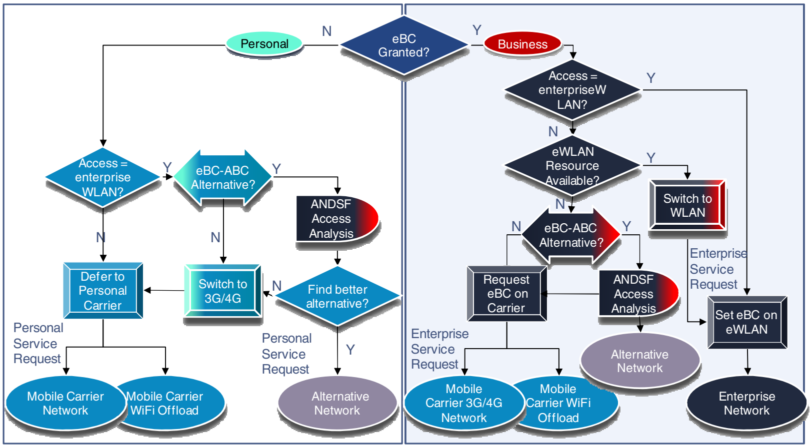

Fig. 3. ANDSF in BYOD usage

If a funded business request arrives on the eWLAN, it goes ahead, but if it arrives from the carrier's network, the device is instructed to switch to the eWLAN, i.e. perform 'force-on-net'. When there are no sufficient eWLAN resources, the Enterprise can still look for an alternative among the hospitality partners nearby. The UE device contacts the eANDSF and downloads the corporate preferred partner list in the vicinity. If, as a result of the eBC computation, the carrier's QoE and

Affordability are superior to the hospitality partners, the carrier's network will be chosen and the access network will be switched over, if necessary.

Alternatively, the device re-launches the service request towards the carrier and it is up to the carrier to serve it or offload it, using its own ANDSF partners with its own policies. In Figure 4, switching from the carrier's 3G access to eWLAN is shown.

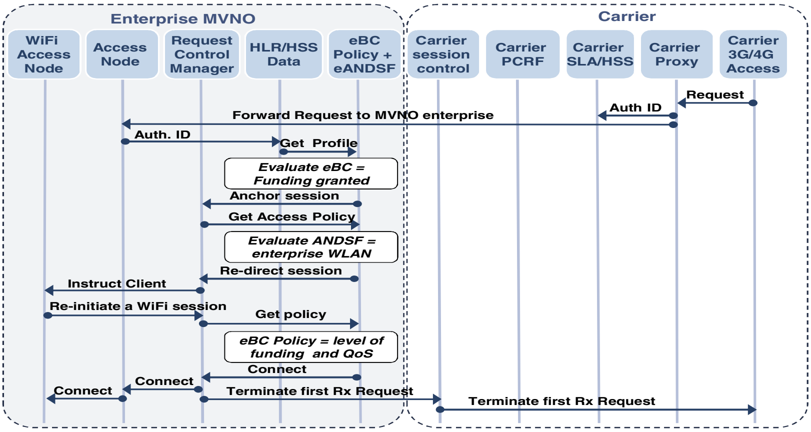

Fig. 4. Switching Access from 3G/4G to WLAN – Forced-on-Net

Requests that are not granted eBC status are deferred back to the carrier's network, to be charged to the user's personal account. If the unfunded request comes over the eWLAN, it will be transferred. However, the Enterprise can still support employees' access selection and protect BYOD devices by providing secure preferred partner, and by using the safer eANDSF. Employees can still benefit from enterprise negotiated deals with the preferred hospitality businesses.

In this example, the carrier forwards the request to the Enterprise as the Home network. The Enterprise authenticates the user and authorizes the service via the eBC Policy. The request is managed in a proxy function which interacts with the eBC policy and the proposed eANDSF. In this scenario, the eANDSF policy decides to use the eWLAN. It may still look for alternatives during peak hours or for a non-urgent session, according to its QoE vector that is received from the eBC Policy server.

In Figure 5, the scenario of switching from eWLAN to carrier's 3G or 4G is shown. The eWLAN session is assessed by internal proxy and eBC server.

In this scenario, a request on the eWLAN is not granted funding and is deemed 'Personal'. The user is notified that an enterprise service is not available and is given the choice of alternative access network prioritized by the Enterprise or the carrier's normal service. In this scenario, the eANDSF analysis shows that the carrier's network is still best value and the user selects it manually. Performing this automatically could be configured, as it is today, on the device. The request is re-launched towards the carrier access network, where the user is authenticated against the personal account, with the personal quota and charging band. The session is connected according to the carrier's policy and will be charged to the user directly.

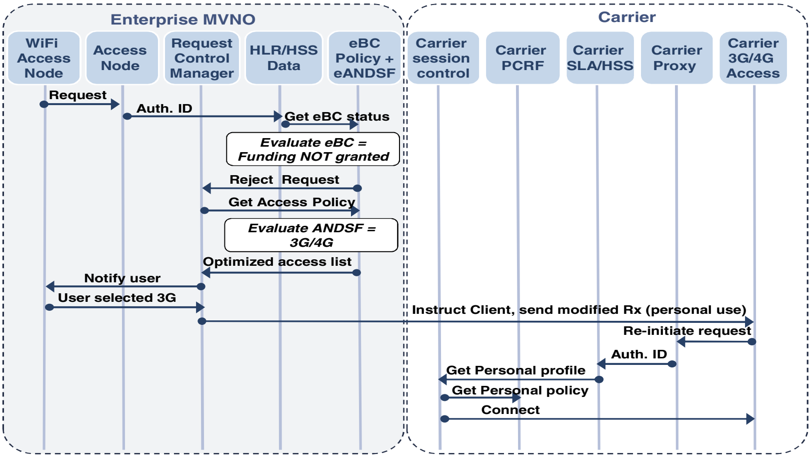

Fig. 5. Switching Access from WLAN to 3G/4G – Forced-off-Net

6 The Context Factors (STANDS and CART)

The network selection decision needs to consider both QoE and Affordability and keep the cost in proportion to required QoE. The QoE requirements are defined by a set of factors - the STANDS (Spatial, Temporal, Activity, Network-type, Destination and Service-type) on the eBC policy server ([19]). Affordability level is not just ability to pay, but also ‘cost tolerance’, the willingness to pay in a particular circumstance. Affordability is derived from the CART (Cost band, Available quota, Role uplift, Time limits) factors. In selecting which access network to use, the required QoE level needs to be compared with the quality level of the offered service and the Affordability needs to be compared with the perceived service cost, as far as it is known. Other human factors may also influence the decision. For example, the lack of available alternatives in the vicinity, in which case both QoE and Affordability are immaterial for a crucial service delivery. Another such factor is the ability to postpone the requested service until a better or cheaper connection is available.

To evaluate QoE, the Enterprise determines the eBC status by evaluating the dynamic STANDS factors, which are computed from sources of data that are available to the Enterprise (email, calendar, server logins, work-schedules etc.). An important source is the service request with details of user ID, destination and service media - see [19]. The STANDS Factors include:

- Spatial aspect (roaming, regional, at-home, at-work);
- Temporal aspect (calendar, hour, date, lunch-hour);
- Activity engagement (holiday, sick, booked activity e.g. customer visits);
- Network type (mobile/fixed, enterprise, hotspots);
- Destination type (human/machine, approved/banned);
- Service type (media, conversational).

The STANDS factors describe the service request circumstances i.e. the Task context. Such Tasks can be Routine-work, Travel, Abroad or Essential-job. Applying customizable factor weightings produces a Task score that represents the priority and desirability that the Enterprise assigns to this service for the Task. The Tasks are prioritized further, to reflect the urgency and importance that the Enterprise places on a quality delivery of this service, i.e. an enterprise-generated QoE vector.

While the STANDS factors are instrumental in defining QoE, the CART factors are crucial to establishing Affordability. Affordability is not merely a question of cost, but also comparative spending power and willingness against budgets and perceived session priority. The CART factors represent affordability and spending privileges. Unlike the dynamic environmental STANDS factors that are session-related, the CART factors are pre-determined and related to the user.

The CART factors include:

– Cost band (approved level of spending) which is a level of charging that may be approved for users according to their role and grade within the organization. In a flat rate charging regime, this is the quota status, which entails higher prices when the threshold is exceeded, especially when roaming.
– Available credit, quotas and budgets, indicate remaining spending power. If there is no credit left, the Enterprise may revert back to personal use.
– Role/grade uplift represents privileges within the Enterprise that may be granted per seniority or particular job requirements. For example, higher budget may be granted if the user's role entails time-critical activities.
– Time limits (duration limits and re-validation periods) are imposed on long sessions but may be relaxed for a particular activity, e.g. monitoring security cameras. Duration limits can achieve 'fair usage', letting in other users in congested networks.

The scalar values of the CART factors are 'normalized' to enable comparison regardless of different measure units. Like the STANDS, the CART factors are assigned weights that reflect their importance within the Task. The CART prioritization values are assigned within each type of Task.

The QoE and Affordability vectors are derived from the STANDS and the CART by applying prioritization. These vectors are computed, using SAW (Simple Additive Weighting) techniques that inject enterprise objectives and priorities in the form of weighting. The STANDS factors prioritization discovers the 'prevailing' Task (Local Travel, for example) that the user is engaged in while requesting the service. This prevailing Task identifies the weighting ratios to apply to the CART factors. Computing a QoE Vector (QV) requires first to apply the Task prioritization to the Task score margin. Highest Task scores are the best fit to the Enterprise objectives.

For Threshold THn, Task TTn, Task weighting ratio TTWn and QoE vector QV:
If TH= {TH1,TH2,...THn} and TTW = {TTW1, TTW2...TTWn}
Then, Threshold Margin THMn = TTn -THn and QV = THMn · TTWn. (1)

The second step assesses the CART factors. CART parameters (measured as 1-5, representing very-high/high/mid/low/very-low ratios) are taken from employees' profile data and their prioritization per Task is applied. Priorities must add up to 1. The Affordability vector is calculated from the weighted CART factors:

If CART factors are: CU:= CiUj and their weighting ratios within each Task are in CT:= CiTn, then → Affordability Vector AV = CiUj · CiTn. (2)

The third step compares QoE Vector (QV) and the Affordability Vector (AV) with measurement of user satisfaction from previous services deliveries by the various access providers. MOS (Mean Opinion Score) is used to measure subjective assessments, having gathered feedback via after-session messaging. Keeping QoE and Affordability as two separate criteria helps users to respond sensibly and provides more flexibility. Figure 6 shows a worked example of the three steps in the evaluation of a session request, in order to find the 'Affordable Best Connection'.

Computing Affordable Best Connection

1. Establish eBC Task and prioritize it

Threshold = 45.00

eBC Task	eBC scores	eBC margins per scenario	Importance % within Task	computed STANDS Scalar
Routine	36.00	-9.00	0.10	-0.90
@Home	42.50	-2.50	0.05	-0.13
Local travel	58.00	13.00	0.20	***2.60*** QoE vector
Essential job	24.31	-20.69	0.40	-8.28
Abroad	38.33	-6.67	0.25	-1.67
			1.00	

2. Establish user's affordability and privilege uplifts per eBC Task

CART	User profile data current level 1-5	Importance % within Task	computed CART scalar
Cost band	5.00	0.25	1.25
Available budget	4.00	0.40	1.60
Role/grade uplift	2.00	0.25	0.50
Time allowance	1.00	0.10	0.10
		1.00	***3.45***=Affordability

3. Compare with MOS values per Access Provider

MOS (1-5)	Required Level	User's Carrier	Hospitality	Ad-hoc WiFi
QoE	***2.60***	3.00	4.00	2.00
Affordability	***3.45***	2.00	1.00	1.00
	6.05	***5.00***	***5.00***	***3.00***

Fig. 6. Example of computed Affordable Best Connection

As shown in this example, the results may favor one vector or or both. Here the 3G carrier is more affordable (e.g. the user is travelling locally - no roaming charges), but the hospitality partner provides higher quality service, e.g. WiFi for video conference. Comparing the totals of both vectors with MOS for both criteria may provide a 'tie', as shown in this example (both carrier and hospitality =5.0), so further decision is needed. As a rule, higher affordability vector wins (carrier = 2.0), rather than the higher QoE, but precedence can be configured per Task context e.g. QoE may dominate the decision for 'Essential Job', while 'Routine' remains Affordability led.

7 Quantifying Cost Savings

A cost saving model can be a useful tool for enterprises to assess the potential benefits from selecting access networks for their employees. Such a model has to assess cost per session, not per megabyte, because the cost improvements are achieved for each session. Unfortunately, most access providers charge for bandwidth usage, not for sessions. Therefore, to quantify cost saving, the model must compute the Average Cost per Session (ACpS) first, taking account of average consumed bandwidth per session, multiplied by the bandwidth charges. This needs to be done for each of the delivering network types: eWLAN, 3G/4G, Hospitality.

Calculating ACpS per network depends on a great many scenarios, a wide range of bandwidth usage patterns and just as many charging regimes. Even if average bandwidth per session is obtained, its costs cannot be generalized. For example, the bandwidth in 'flat rate' is part of the average cost, but also a portion of the higher rate when the limit is exceeded. Roaming charges as well as local charges should be factored in, the proportion of which varies between business and personal. Cost-per-megabyte has already been declared as 'NP Hard' in [22], i.e. too complex to calculate, and we have to concur that ACpS cannot be reliably modeled.

However, each enterprise can still estimate its own costs and bandwidth usage. These estimates are based on obtained usage statistics from the internal network, and the cost of providing eWLAN/LAN capacity from equipment and maintenance prices, allowing for the write-off period for infrastructure investment. It is important to factor in the value of using up spare capacity, when the investment cost is not incremental per session, i.e. increasing benefits of sunk costs.

Specific usage /cost information must also be obtained from the mobile carriers and hospitality agents for comparison. Carrier usage/charging data is derived from historical accounts, carrier agreements and business expenses processing. Hospitality agents have simpler charging models (per hour/day) but the number of sessions needs to be estimated, if not available.

For such a specific case of cost saving assessment, we provide a model that indicates the cost sensitivity to shifting access networks, as shown in the cost saving sensitivity model in Figure 7.

To test sensitivity, the calculated example shows the change when 10 %, 20% and 30% of sessions are shifted from one access network to another, to optimize service delivery costs. This model includes three scenarios: On-site business sessions (shifting sessions from 3G/4G to eWLAN), Off-site business sessions (shifting sessions from 3G/4G to hospitality) and On-site personal (shifting sessions from eWLAN to 3G/4G). The scenario of off-site personal session on hospitality access is not needed since it is not charged to the Enterprise but is paid directly by the user.

The estimated ACpS per network type in this example are merely for illustration. Note that it is assumed that Personal ACpS is higher than Business ACpS, not just due to higher consumer prices, but also due to higher bandwidth consumption average – personal usage is more likely to include pictures and video streaming while most business sessions involve email, text and browsing. We also assumed a discounted rate for hospitality WiFi that is on the Enterprise preferred list.

Quantify Savings p.a.	Business Calls			Personal Calls		Costs	Savings
Average Cost per Session:	€ 0.35	€ 2.55	€ 8.00 € 6.50	€ 1.50	€ 3.80	per user	per user
Current	**eWLAN**	**3G/4G**	**Hospitality**	**eWLAN**	**Personal 3G/4G**		
On-site no. Sessions per annum	450.0	350.0		320.0	100.0		
On-site Cost per annum	€ 157.5	€ 892.5		€ 480.0	€ 380.0		
Off-site no. Sessions per annum		500.0	120.0				
Off-site Cost per annum		€ 1,275.0	€ 960.0				
Total Cost per user p.a.	€ 157.5	€ 2,167.5	€ 960.0	€ 480.0	user's cost	€ 3,765.0	
10% change	**eWLAN+10%**	**3G/4G-10%**	**Hospitality+10%**	**eWLAN-10%**	**Personal 3G/4G**	0.10	
On-site no. Sessions per annum	485.0	315.0		288.0	132.0		
On-site Cost per annum	€ 169.8	€ 803.3		€ 432.0	€ 501.6		
Off-site no. Sessions per annum		450.0	132.0				
Off-site Cost per annum		€ 1,147.5	€ 858.0				
Total Cost per user p.a.	€ 169.8	€ 1,950.8	€ 858.0	€ 432.0	user's cost	€ 3,410.5	€ 355
20% change	**eWLAN+20%**	**3G/4G-20%**	**Hospitality+20%**	**eWLAN-20%**	**Personal 3G/4G**	0.20	
On-site no. Sessions per annum	548.0	252.0		230.4	189.6		
On-site Cost per annum	€ 191.8	€ 642.6		€ 345.6	€ 720.5		
Off-site no. Sessions per annum		360.0	158.4				
Off-site Cost per annum		€ 918.0	€ 1,029.6				
Total Cost per user p.a.	€ 191.8	€ 1,560.6	€ 1,029.6	€ 345.6	user's cost	€ 3,127.6	€ 637
30% change	**eWLAN+30%**	**3G/4G-30%**	**Hospitality+30%**	**eWLAN-30%**	**Personal 3G/4G**	0.30	
On-site no. Sessions per annum	623.6	176.4		161.3	258.7		
On-site Cost per annum	€ 218.3	€ 449.8		€ 241.9	€ 983.1		
Off-site no. Sessions per annum		252.0	205.9				
Off-site Cost per annum		€ 642.6	€ 1,338.5				
Total Cost per user p.a.	€ 218.3	€ 1,092.4	€ 1,338.5	€ 241.9	user's cost	€ 2,891.1	€ 874

Fig. 7. Cost Saving Sensitivity Model – Case Study

In this example, a 1000 strong enterprise can save 355,000 Euros per year with just 10% session shifting, and 874,000 Euros with 30% changes of access per year. We acknowledge that these results entirely hinge on the relative differences between the ACpS rates in each network, which could not be accurately ascertained in a generalized model, however, this example shows that there is remarkable cost elasticity for relatively small number of access shifts, indicating that the eBC/eANDSF access selection solution is well worthwhile.

8 Conclusions

In this paper we focus on satisfying the enterprise needs for best access selection. An enterprise adopting BYOD has a particular issue with protecting its own network resources from a surge of unproductive personal traffic. The enterprise seeks to optimize usage of spare capacity on its internal network resources rather than paying mobile carrier prices for sessions initiated on-site. It also seeks to select hospitality partners who not only offer discounts but can also be relied on to provide secure, quality connectivity. This means that the enterprise should 'force-on-net' business traffic and 'force-off-net' personal traffic, and should indicate to off-site employees which WiFi partner to choose.

This paper proposes that enterprises use the eBC techniques to establish users' context and execute access selection according to the resulting business status. The decision process needs to consider the STANDS factors for the requested level of QoE, and the CART factors for the Affordability aspect. For personal service requests that are not allowed on-net, the Enterprise will suggest an alternative, either the carrier's

3G/4G or local non-3GPP partner. For business usage, when employees are out-of-range or when the Enterprise WLAN is overloaded, alternative access networks will be selected. To do this, an enterprise-centric 3GPP-compatible ANDSF is proposed. This eANDSF maintains corporate access selection policies and corporate preferred partner list, with their negotiated corporate discounts.

By selecting the most cost-effective access network and optimizing utilization of internal network resources, enterprises can realize considerable savings. Although the potential savings can be computed case by case, it is not possible to produce a generalized model, however an illustrative specific case calculation shows that there is considerable cost sensitivity to shifting access network of service requests, hence there are considerable benefits for the Enterprise.

References

1. Decisive Analytics: Mobile Consumerization Trends & Perceptions IT Executive and CEO Survey (2012)
2. Gazis, V., Alonistioti, N., Merakos, L.: Toward a generic Always Best Connected capability in integrated WLAN/UMTS Cellular mobile networks (and beyond). IEEE Wireless Communications 12(3) (2005)
3. Cananéa, I., Mariz, D., Kelner, J., Sadok, D.: An On-line Access Selection Algorithm for ABC Networks Supporting Elastic Services. In: IEEE WCNC Proceedings (2008)
4. Ji, Z., Ganchev, I., O'Droma, M.: An iWBC Consumer Application for 'Always Best Connected and Best Served': Design and Implementation. IEEE Transactions on Consumer Electronics 57(2) (2011)
5. Kellokoski, J., Hamalainen, T.: User-Centric Approach to Always-Best-Connected Networks. In: IEEE ICUMT (2011)
6. Yiping, C., Yuhang, Y.: A new 4G architecture providing multimode terminals always best connected services. IEEE Wireless Communications (2007)
7. Chen, Y., Deng, C., Yang, Y.: Access Discovery in Always Best Connected Networks. IEEE (2008)
8. Lahby, M., Leghris, C., Adib, A.: A hybrid Approach for Network Selection in Heterogeneous Multi-Access Environments. IEEE (2011)
9. Vodafone user guide: Enterprise Install Guide: Vodafone Mobile Broadband (2011)
10. Savitha, K., Chandrasekar, C.: Vertical Handover decision schemes using SAW and WPM for Network selection in Heterogeneous Wireless Networks. In: GJCST (2011)
11. 3GPP TS 23.402: Architecture enhancements for non-3GPP accesses (Release 11)
12. Corici, M., Fiedler, J., Magedanz, T., Vingarzan, D.: Access Network Discovery and Selection in the Future Wireless Communication. ACM, Springer (2011)
13. Chandra, R., Padhye, J., Ravindranath, L., Wolman, A.: Beacon-Stuffing: Wi-Fi Without Associations. Microsoft Research (2007)
14. Khirman, S., Henriksen, P.: Relationship between Quality-of-Service and Quality-of-Experience for Public Internet Service. In: PAM (2001)
15. 3GPP TS 24.302: Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks Stage 3 (Release 11)
16. Copeland, R., Crespi, N.: Analyzing consumerization - should enterprise Business Context determine session policy decisions? In: IEEE ICIN (2012)

17. Copeland, R., Crespi, N.: Controlling enterprise context-based session policy and mapping it to mobile broadband policy rules. In: IEEE ICIN (2012)
18. Copeland, R., Crespi, N.: Establishing enterprise Business Context (eBC) for service policy decision in mobile broadband networks. In: ICCCN ContextQoS (2012)
19. Copeland, R., Crespi, N.: Implementing an enterprise Business Context model for defining Mobile Broadband Policy. In: IEEE CSNM (2012)
20. TalebiFard, V., Leung, C.M.: A Dynamic Context-Aware Access Network Selection for Handover in Heterogeneous Network Environments. In: IEEE Infocom MobiWorld (2011)
21. Fiedler, M., Hossfeld, T., Tran-Gia, P.: A Generic Quantitative Relationship between Quality of Experience and Quality of Service. In: IEEE Network (2010)
22. Gazis, V., Houssos, N., Alonistioti, N., Merakos, L.: On the Complexity of "Always Best Connected" in 4G Mobile Networks. In: VTC (2003)