"Always Best Connected" Enabled 4G Wireless World

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ABSTRACT

The evolution of a fully "Always Best Connected" ABC enabled 'fourth generation wireless world', 4GWW, paradigm is addressed in this paper. It addresses the subjective and objective nature of the ABC concept from the viewpoints of the various wireless network 'players'. ABC definitions corresponding to users' viewpoints are considered primary and given priority, and models for users' best connectivity solutions are proposed. A proposal for a type of reference terminal architecture and the essential elements of reconfigurability involved in the communication layers for ABC are presented, together with a proposal for the development of the physical layer support for ABC, as well as outlining state-of-the art and research challenges in the components of various layer entities. The inherent QoS inadequacies associated with "all-IP" wireless networking, and the implication for ABC offerings are highlighted. In exploring the 4GWW evolutionary context initial descriptions for evolving wireless network types, environments and terminals are set down.

I. INTRODUCTION

The "Always Best Connected", *ABC*, concept may be considered as the vision behind vertical handoff technologies from such mobile wireless accesses and networks as GSM, IS-136, EDGE, GPRS or UMTS to unlicensed spectrum technologies such as 802.11a/b/g. In so far as ABC has been considered, it has been in this kind of context, i.e. a dual or multi-mode user terminal being able to choose an access from among a number of single-access wireless networks, SAcWiN[1], and now gradually also MAcWiN[2]), the choice being made according to user perceived cost, bandwidth and/or QoS criteria.

In evolving a 4GWW[3] paradigm, the ABC concept itself [1] and the contexts in which it will find application need to be evolved and extended to include some new dimensions, such as adaptive applications, open interworking and interoperating multiple single-access and multi-access wireless networks (MuSAcWiN[4] & MuMAcWiN[5]), reconfigurable terminals and networks, and operator competition. Exploring and defining the new scenarios, network/service/terminal environments and business models implicit in positing ABC as a key and integral feature of the 4GWW necessitate the setting down

[1] SAcWiN, a *Single Access Wireless Network, a kin to traditionally vertically contained wireless network, provides users with a single access, SAc, technology to a core unified network. While there may be variations in the air interface of the access (e.g. as a function of the service supported) these variations remain within the values of certain general common constant physical attributes of the access (e.g. the modulation format or multiple access technology and rules), to the extent that it is valid to still refer to it as a single access technology.*

[2] *MAcWiN here is defined as a network providing different (more than one) access technologies to a core unified network. Such access technologies are sufficiently different to merit being so distinguished (e.g. having different values for defining physical layer attributes, such as the modulation scheme). Which access technology is invoked by the user or the network will be determined dynamically on the basis of certain criteria etc., or by prior agreement (e.g. between the user, and network operator, and maybe also by service provider) seeking to meet certain criteria for the communications access, connection and information transfer.*

[3] *4GWW, Fourth Generation Wireless World, here includes fixed and mobile, terrestrial and satellite wireless access networks.*

[4] *MuSAcWiN, Multiple Single-Access Wireless Networks, means more than one SAcWiN wireless network (e.g. the traditionally vertically contained network) providing a single access, SAc, technology. At present this single access will handle only one logical or real communication connection. However in due course handling of several connections on a single access will be normal, e.g. accessing a server database while also simultaneously maintaining a telephone conversation all on the same single access.*

[5] *MuMAcWiN, Multiple Multi-Access Wireless Networks, means more than one MAcWiN.*

of carefully crafted definitions of many new terms and system components, first among which is the definition of ABC itself. With a focus on the ABC concept, this paper presents early ANWIRE[6] efforts to set out considerations and initial definitions which help lay the groundwork of the new 4GWW paradigm, with implicit suggestions for the challenges and possible directions for R&D efforts.

II. "ABC" FOR WHOM

ABC encompasses a vision, which may be defined differently by different players. Interpretations and viewpoints will vary as function of the 'interest' of the player. The definition of criteria for 'better' and 'best' will consist of objective and subjective aspects. Normally not only will categories of players such as users, network operators and service providers represent broad classes of expectations and requirements of what ABC is, but there will also be a wide range of divergent viewpoints within each category related to such matters as socio-politico and socio-economic environments, regulatory environments, user population densities, service specialization, and geographic/territorial environments. Immediately following are typical operator, user and service provider viewpoints, pared back to avoid complexity.

A. ABC from an Operator's viewpoint

Operators like to consider that users will receive the best communication access and connection possible following the operator's business model focused (in the future) less on 'bits' and more on providing managed and carefully tariffed access to services. Users for the most part should be kept satisfied enough not to want to change operator, while operators maximize profit. In that context it is good for the operator to either control or have a direct relationship with each service provider (as well as with each user). This point of view provides flexibility in upgrading, and looking to the future it facilitates the orderly migration from proprietary systems to open ones, and allows the operator to maintain control of the communications infrastructure.

The Ericsson Mobile Operator WLAN solution [2] is an example of the operator's viewpoint in present day evolving network environment. Nokia has released a dual-mode PC-CARD, that supports GPRS and WLAN out of the box [3]. Its operation follows the same principles as Ericsson's, i.e. it extends the GPRS subscriber base to cover those in public WiFi hotspots, a dual SAcWiNT[7].

While market forces are for some time now driving operators to listen and respond more carefully to users' requirements and demands, there are still vestiges about of the legacy thinking that they (the operators) "know what is best for the user" both now and into the future. This usually technology based thinking may be extended to all non-user technological and regulatory players in the telecommunications arena today. An understandable dimension to this is the enormous momentum created by major technological decisions, especially where open standards are a part of the picture. Some such decisions succeed in the market place (e.g. GSM, TCP/IP) and some fail (e.g. OSI protocols, various extended- and high-definition television solutions, Iridium). A good example of a currently accepted technological decision for the future, an important one from an ABC perspective and one for which success or failure is still an open question, is the 'decision' to migrate to "all-IP" for all communication services.

B. ABC from a User's viewpoint

A user's more radical non-technical point of view would be to see ABC as a matter of inexpensive Internet connectivity and seamless access, if possible, to all types of present and future teleservices. It is possible for instance to imagine certain implementation forms of Ad Hoc networking services (e.g. for SMS in a student campus environment) which would have high consumer value but which could exclude traditional mobile network operators. The two key components uppermost in users' minds defining better and best will be price/performance ratio and comprehensive service access. In that context for instance the market forces of a regulated competition engendered by an environment of multiple networks, service providers and operators will be viewed positively as naturally serving such requirements

Perhaps a stage will be reached where operators' competition may be a consideration for each call/session. For example whenever a phone or data call is to be made, if the user is within the network access footprints (NAF[8]) of several operators', then obviously the user would like, in a painless user-friendly way, to choose the network access which currently offers the 'best' or most acceptable price/performance ratio. Performance here from a technical viewpoint may be largely reduced to a set of values for QoS attributes. Important also to the user is the need to control the best billing option available at any time. Very likely users will want to develop personalized billing profiles, with for instance operator and service specific options e.g. service subscriber, anonymous prepaid, digi-pay per service usage or authenticated organization account (e.g. university, employer).

Such user requirements will present major business-model challenges, quite apart from the technical and regulatory challenges required to create a multiple multi-access wireless network environment, MuMAcWiNE[9]. Also, the security associations between users and Access Point owners need a flexible management framework and multi-featured solutions, which can create and manage the terms of access – another major R&D challenge (including,

[6] *This work has been produced in the framework of the project ANWIRE (www.anwire.org), which is funded by the European Community under the contract IST-2001-38835.*

[7] *SAcWiNT: a SAcWiN terminal*

[8] *NAF here is defined as a geographic area (e.g. cell) from within which access to the network is feasible.*

[9] *MuMAcWiNE (multiple multi-access wireless network environment) means an environment of overlapping NAFs of multi-access wireless networks.*

within this, security issues related to terminal reconfigurability, SDR software downloads etc.). Appropriate solutions for that framework will need to take into account conflicting requirements and needs.

C. ABC from a Service Provider's viewpoint

Service provider's viewpoint is focused on the open nature of intuitive interfaces (both to the user's requests and to the network provider's access and billing mechanisms) and flexibility in development and deploying its services in third party networks. The service provider is less interested in technical matters and more focused on creating and distributing attractive services, as they will provide new incentives for accessing the wireless networks. If the services are popular, more people will use the networks, and, hence, more revenue will be created for the network providers. The same will be true for users, since advanced services and advanced network infrastructure will be offered to them.

D. ABC and multiple overlapping wireless access networks, MOWAN[10]

From the above the ABC vision can be seen as a controversial concept. Much R&D work will be required which will address, to put it simply, the underlying technological and business assumptions to bring clarity and especially a clear evolutionary road map. In any case, for the moment integrating, from the user's viewpoint, wireless networks, which already exist or are upcoming in MuSAcWiNEs[11] and MuMAcWiNEs[12], creates many challenges to be faced in a first step towards the evolution of the ABC enabled 4GWW paradigm.

A basic assumption for a potential ABC environment to exist is that a MuSAcWiNE of at least two networks exists and a user with an appropriate multiple single- or multi-access wireless network terminal (MuSAcWiNT[13] or MuMAcWiNT[14]) can gain access to at least two of them. Even in such a minimalist situation, the criteria, factors, players and processes involved in making the access decision is crucial to the understanding of 'best'/'better' in each circumstance. For the application of the ABC concept in future 4G networks this is probably its first and simplest level. ANWIRE partners are generally agreed that in 4G networks greater and greater levels of dynamic adaptability and reconfigurability of user access are to be implemented and enabled. This complexity towards 4GWW is further multiplied if user devices/terminals are empowered to have simultaneous multiple connections (SMC) in MuMAcWiNEs using multiple *simultaneous* single-access connection wireless network terminals (MuSSACWiNT[15]) or, with greater complexity, multiple *simultaneous* multi-access connections terminals (MuSMACT[16]). Adding to the order of complexity would be the enabling of hot access change (HAC[17]), with or without service interruption (HACNoSI[18] or HACSI), within or across networks.

One way of gauging the eventual operational success of an ABC enabled 4GWW is that a GWW terminal will have the ability to dynamically have the ABC access for any and all of their connections all the time (HAC) for all networks present to the terminal (i.e. their NAFs enclose the terminal). An extension of the vision of multiple devices in a Personal Area Network (PAN), collaborating to achieve the best communication path possible, is seen as part and parcel of ABC concept. Justification for this kind of thinking may be seen in present day technological trends and promises (e.g. Ad Hoc networks within existing traditional wireless network environments, which may be viewed as a technological solution responding primarily to the user's ABC viewpoint), and the growing sophistication of MuSAcWiNTs and the access offerings available to them. Perhaps the latter could be considered a win-win common view of ABC for users, manufacturers and network providers alike.

III. CHOOSING A USER'S "BEST" CONNECTIVITY SOLUTION

The best connectivity solution can be chosen only after accurate analysis of cost and benefits of each access solution. This analysis should be done from the point of view of users, operators and service providers. Accordingly, in MuSAcWiNEs, the user should always be connected through the access solution, which satisfies one of the following conditions (achieved transparently to the user, but defined in the interest of the user primarily):

i. Minimizing the following cost function [4]:

$$f(n) = w_b \cdot \ln \frac{1}{B_n} + w_e \cdot \ln E_n + w_c \cdot \ln C_n ,$$

where B_n is the bandwidth of network n, E_n is the power consumption of network n, C_n is the cost of

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[10] *MOAWN, Multiple overlapping wireless access networks, a generic term inclusive of MuMAcWiNEs and MuSAcWiNEs*

[11] *MuSAcWiNE* (multiple single-access wireless networks environment): *an environment of overlapping NAF of single-access wireless networks.*

[12] *MuMAcWiNE* (multiple multi-access wireless networks environment): *an environment of overlapping NAF of multi-access wireless networks.*

[13] *MuSAcWiNT, (multiple single-access wireless network terminal): are terminals, which may establish and operate multiple single-access connections, though only one access to one network may be operating at any one time. Present dual mode terminals are usually MuSAcWiNT.*

[14] *MuMAcWiNT (multiple multi-access wireless network terminal):are terminals, which may establish and operate multi-access connections over multiple networks, though only accesses to one network may be operating at any one time.*

[15] *MuSSACWiNT (multiple simultaneous single-access wireless network terminals): terminals which may establish and operate multiple single-access connections over multiple networks simultaneously (e.g. simultaneous handling of an EDGE and a WiFi connection by one terminal).*

[16] *MuSMAcWiNT are terminals, which may establish and operate multiple multi-access connections over multiple networks simultaneously.*

[17] *HAC is where a terminal's access to a network is changed (to another access technology within the same network or to that of another network). This is analogous to the hand-over concept in SAcWiNE, but the structure of it, the reasons for it and consequences of it are quite different so a different term is needed. A typical reason for HAC would be the availability of a better option and offer for the same service access from another wireless network to which the user has come to have access.*

[18] *HACNoSI/HACSI: HAC without/with (apparent) loss of connection to the network service being accessed.*

network n, w_i is the weight of each parameter ($\sum w_i = 1$). These terms will be interdependent in a complex way. Especially considering QoS issues in "all-IP" wireless networks, C_n will be a strong function of q, a measure of this (c.f. iii below), and B_n.

ii. Maximizing the level of perceived QoS;

iii. Minimizing cost provided that a certain QoS constraints are satisfied.
The cost may be evaluated by using the cost function cited above. Then a *utility function* is used to choose the best offer according to two factors: price and quality [5].

$$u = [\alpha(q - \overline{q}) + (1-\alpha)(\overline{p} - p)]\Theta(\overline{p} - p)\Theta(q - \overline{q}),$$

with $\begin{cases} \Theta(x) = 1 \text{ if } x > 0 \\ \Theta(x) = 0 \text{ else,} \end{cases}$

where q is the evaluated quality value, $\overline{q}$ is the minimum quality a user is willing to accept, p is the price of the network connection, $\overline{p}$ is the maximum price user is willing to accept, α is a parameter between 0 and 1 which indicates the user sensitivity between quality and cost. For each access network available, the user software applies the *utility function* and chooses the network with the maximum value u. Of particular difficulty here and another subject for much challenging research are the development of models to evaluate q and $\overline{q}$.

IV. ENABLING TECHNOLOGIES

In this section we present the recent technological achievements, which can make ABC something real. The section is organized in different subsections depending on the protocol layers involved. Each subsection includes comments on the relevant state of the art technology and some of the open issues yet to be researched (e.g. what problems the current technologies can not handle). Also some future trends are identified.

A. System/Terminal Architecture

The development of technologies based on the ABC concept will imply a gradual migration from today's vertical closed networks to future horizontal layered "all-IP" networks where all may share common backbone IP networks and only the access technologies differ. From an architectural point of view, this objective drives research efforts in three main directions:

i. enhancements of the existing architectures to enable the necessary features (vertical handovers, different services charging policies, etc.);
ii. integration of the existing architectures (much more complex network management systems);
iii. development of new terminal architecture.

Figure 1 depicts a possible terminal architecture which in this still general form may represent not just MuSAcWiNT but also the other three more sophisticated terminal class types. Without loss of generality, it is assumed that mobility management is provided by a well-supported cellular IP layer [1].

In addition to the well-known layers the proposed MuSSAcWiNT architecture must include the following ones: several physical layer *communication interfaces* (one per each type of access network; only terrestrial networks are mentioned in fig.1, but in due course satellite network physical layer entities will appear alongside these); *convergence layer* (providing a unique link-layer service interface to the upper layers); *switcher layer* (which "elects" the access technology/network that provides best connection for any particular situation); *middleware (API) layer* (providing an interface to the application layer in order to inform the access selection process about the application requirements and, in the other direction, inform the applications in situations when these requirements cannot be fulfilled); 'vertical' *resource repository layer* (constitutes the interface between the middleware (API) layer and the convergence layer; all the ABC policies will be implemented here).

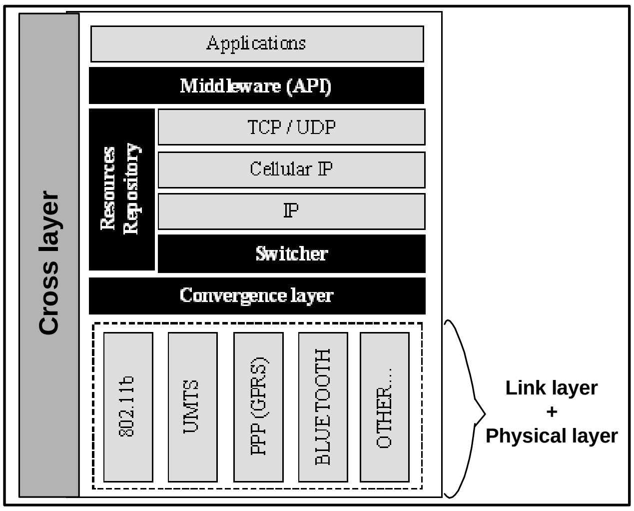

Figure 1. Terminal architecture for MuSSAcWiNT & other classes

B. Reconfigurability in communication layers

To reconfigure any part of the communication layer it is necessary for the network to have some intelligence and reconfiguration control. The intelligence decides what part(s) of the network should be reconfigured, based on the relevant information supplied to it, and then gets the reconfiguration controller to implement these decisions in the appropriate way in the hardware and/or software modules. The intelligent reconfigurability for the ABC concept should take into account the following essential components (Figure 2): reconfigurable network, software reconfigurable language, radio environment, user environment (the applications profiles, etc…), network environment (i.e. the current states of the different hardware and software components of the physical (PHY), MAC layers of the network).

A key architectural component supporting reconfigurability control and application adaptability, as well as adaptability of link, physical and other layers will be the through the development of the *cross layer* protocol entity shown in fig.1. Developing its functionality, communication paths, and layer boundary interfaces will provide interesting research challenges, [6] and references therein.

C. SDR in physical layer

Software defined radio (SDR) is regarded as an important scheme to implement the adaptability and reconfigurability at any communication layer. However, in this paper we consider the SDR in 'narrow sense', i.e. only having an impact on the radio resource management (RRM) and spectrum management by physical layer (PHY) reconfigurability [7]. Three modules are essential here (Figure 2):

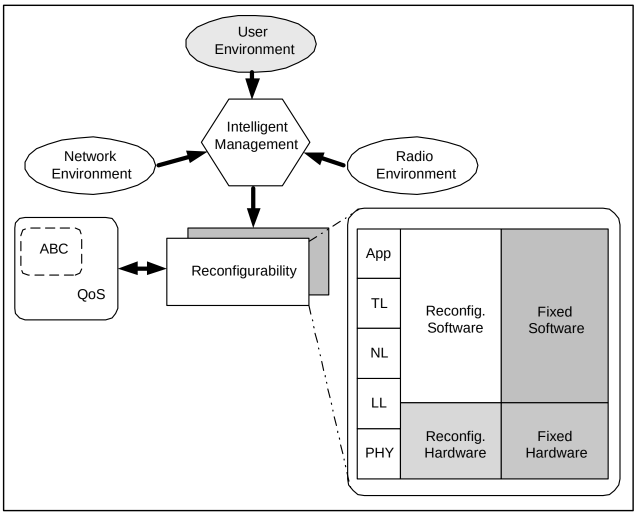

Figure 2. Essential elements of reconfigurability involved in the communication layers for ABC

i. **Hardware reconfiguration for ABC** includes reconfiguration of firmware, digital signal processor (DSP), FPGAs, and multiple RF sections utilizing microelectromechanical switches (MEMS). Elements which present significant challenges in seeking a comprehensive intelligent reconfigurable physical layer include (Figure 3): Smart Antennas, Receiver/Transmitter architecture: MIMO elements, Reception/Transmission algorithm adopted, all of which have complex dependencies on modulation scheme, signal bandwidth and operating frequency, air interface channel characteristics, transmit power energy resources and efficiency, and so forth.

ii. **Software Reconfiguration for ABC** should be carried out by the introduction of new program code in the user terminal, with the aim of modifying its configuration and/or contents. The downloading process encompasses not only the protocol or the software entities to be downloaded, but also the method and performance of the download, [8]. Figure 3 illustrates a categorization of software reconfigurability for the ABC strategy:

- Lower-level software components (e.g. physical protocol entities for more structural modification of the air interface);
- Software components and parameters for modification of the PHY layer, including DSP algorithms and FPGA reconfiguration (addressing framing and channelising issues, modulation schemes, power amplifier efficiency and linearisation algorithms and settings, and so forth.

The evolution of software downloading for ABC software radio reconfigurability may move through the following stages [9]:

- <u>Out-call (static download)</u>: software component are downloaded into a secure sandbox for installation at an appropriate time.
- <u>In-call (dynamic download)</u>: software reconfigurability components are download and installed during a call to support dynamic service reconfiguration (for ABC) or distributed processing, requiring over-the air download.

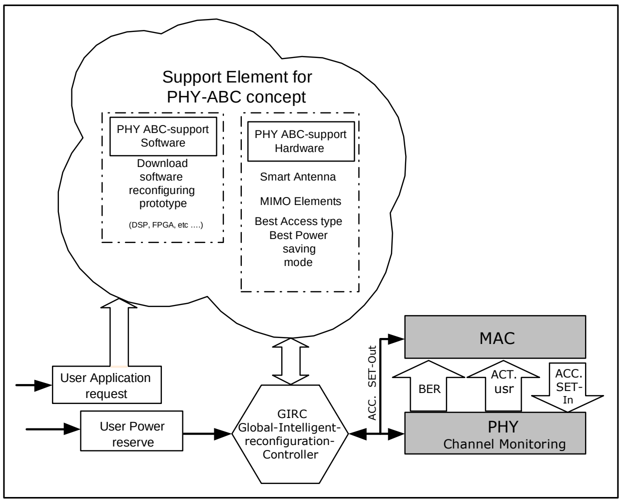

Figure 3: Physical layer support for ABC

iii. **Intelligent Management for ABC** involves on one hand the traditional DSP techniques and classical MAC protocols, and new techniques that permit a joint resource optimization. On the other hand management of reconfigurability and adaptability algorithms including static and dynamic secure downloading schemes, algorithms for assessing user's terminal status, environment, and various players' requirements (all dependent on context scenarios) for satisfying users' service specific ABC expectations will reside here.

We posit the Global Intelligent Reconfiguration Control, GIRC, (Figure 3) as the heart of the intelligent management procedure. GIRC gathers the following information [8]: the end user application, regarding the user profiles and environment; the radio environment; the reconfigurable mobile network environment, regarding the state of the different hardware and software components in the different protocol layers.

D. Convergence layer

Many issues call for designing a uniform wireless-enhanced interface for transmitting IP packets over wireless links. Such an interface (named IP to Wireless interface - IP2W), geared to some LL and PHY radio interfaces, was defined in the BRAIN project [10]. IP2W (only present in the mobiles nodes and access routers) provides a way for the IP layer to interface to a number of different wireless link layer technologies. The main IP2W functions are described in [10], and they provide a good starting point for evolving convergence layer (CL) design for converging an all-IP (IPv6) to a wide range of terrestrial and satellite wireless network air interfaces for the four terminal class types introduced above.

As in IP2W, an implementation of a CL for a specific link layer (LL) technology, adapting the service requirements of different higher layers to the services offered by the LL, will be required. With each level of sophistication –from single connection on single access network to multiple connections to multiple multi-access networks– the challenge of developing robust CL algorithms will grow. The approach of seeking to develop CL families (CLFs), [10], could be usefully adopted.

E. Network layer and Quality of Service issues

The Internet Protocol (IP) was originally designed to exhibit robustness and reliability for the generic network objective of providing logical telecommunication network connections and information delivery in any environment: “if there is a way to the destination IP will find it”!

Nowadays, as the Internet Architecture expands with the proclaimed ambition to support every kind of telecommunication service, it becomes ever more urgent to address an inherent weakness of IP which undermines development of ABC, particularly from the users viewpoint, for connections within certain key services areas. That weakness is the absence of a capacity for any real long term, structured, predictable provision of full Quality of Service (QoS) support. For the network provider another significant inadequacy of IP is the major traffic engineering, TE, problem it presents, which gives rise to serious difficulties in managing network resources efficiently. Users have the operators’ full empathy in this QoS/TE problem inherent in IP. Offering a service for which control of QoS is out of their hands is anathema for traditional telecommunications network engineers.

Apart from ‘throwing bandwidth at this problem’, first efforts at meeting this great technological and business challenge are through the development of technologies to provide preferential treatment of some data flows or flow aggregates. These include the Integrated Services Architecture (IntServ) [11], the Differentiated Services Architecture (DiffServ) [12] and a new sub-IP protocol layer called Multiprotocol label switching (MPLS), [13] and references therein, which can create partially connection-oriented type pipes within nested MPLS domains of the internet established among collaborating networks. These schemes already being implemented in some parts of the wired Internet, can add many QoS benefits and improvements within enabled domains (e.g. for VPNs), do not provide comprehensive solutions to the QoS problems especially for some service offerings, e.g. mission critical services, and bi-directional, or unidirectional, real time services such as IP telephony or Video/TV streaming. Also the nature of the internet (with its ever growing vast numbers of autonomous interworking IP networks, of all sorts sizes, extensions and shapes) makes the possibility of these solutions being omni-present on the internet in the future remote. However extending their technological concepts to the wireless access part of the network is recommended as a step forward, towards addressing QoS issues in wireless IP. The Connection Admission Control (CAC) points which will be the focus for users in seeking QoS offerings and guarantees, will have an important role to play in implementing these and other QoS solutions.

It is worth mentioning that the move from IPv4 to IPv6 does not bring a remedy to this QoS IP flaw, even if there is greater possibility of ‘stitching in’ improvements, and of limited or contained solutions along the lines mentioned above.

IP Mobility

It is interesting to note that the hoped for move to IPv6 may well rely on wireless IP for its success: there will be a vast growth in mobile wireless terminals each requiring at least one fixed IP address, and probably two such addresses to enable a robust mobile IP addressing solution. Solving issues of mobility will be a ‘sine qua non’ for ABC enabled 4GWW. ANWIRE deliverable [1] reviews the state of the art in micro- and macro-mobile IP development.

QoS and Mobility Interactions

Since end-to-end QoS implies the maintenance of state in a router, but mobility and HAC mean the drastic or otherwise modification of the routing path, the question of how the QoS state is re-established after the mobility events and HACs needs to be addressed. Considering the use of IntServ and/or DiffServ (mentioned above), solutions may be possible along the following lines, assuming successful horizontal network interworking:

- QoS state re-establishment in every router in the end-to-end path (IntServ);
- QoS state re-establishment only in the access link (DiffServ);
- hybrid of the two above.

F. Transport layer

Transmission Control Protocol (TCP) is most popular transport layer protocol for the Internet. Originally designed for wired networks, it has been used in wireless networks (including satellite networks [14]) but has not enjoyed the same degree of success due to effects and limitations imposed by wireless environment on the network as well as the mobile terminal requirement limitations. These include (i) bandwidth limitations, (ii) long round trip times (RTT) that affect TCP throughput and increase the interactive delays perceived by the user, (iii) random transmission losses due to environmental characteristics like fading, (iv) user mobility, (v) power consumption.

To resolve these wireless domain TCP performance issues, research mainly has been directed through three different approaches: 1) link layer (LL) solutions (e.g. TCP aware [15] and TCP-Unaware LL Protocols [16]); 2) TCP modifications (e.g. TCP selective acknowledgments options (TCP SACK), [17] Indirect TCP (I-TCP) [18] and mobile M-TCP [19]); and 3) new transport protocols designed specially for wireless networks (e.g. the Wireless Transmission Control Protocol (WTCP) [20]). These have been reviewed in [1] and it is clear that significant progress in developing robust solutions has yet to take place.

V. CONCLUSIONS

In considering the evolution of a fully "Always Best Connected", ABC, enabled 'fourth generation wireless world', 4GWW, paradigm, this paper summarises studies to date on the ABC concept itself undertaken within the ANWIRE thematic network, [1]. It addresses the subjective and objective nature of the ABC concept from the viewpoints of the various wireless network 'players'. In particular ABC definitions, which will respect users' viewpoints, are considered primary and given priority, and models for best connectivity solutions are proposed. In brief form we provide an initial proposal for a type of reference terminal architecture and the essential elements of reconfigurability involved in the communication layers for ABC, with a proposal for the development of the physical layer support for ABC, as well as outlining state-of-the art and research challenges in the components of various entities of the enabling technology in other layers. Some of the serious QoS concerns associated with "all-IP" wireless networking, and all important for ABC offerings were highlighted. In exploring the 4GWW evolutionary context we also set down initial descriptions for evolving wireless network types, environments and terminals.

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