3G NETWORK & SERVICE PROVISION ARCHITECTURE EVOLUTIONS

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Abstract - *Over the last years 3G standardization has been quite active, leading in new directions both in the network and the service provision architecture. The explosive growth of the Internet and the increasing demand for all sorts of IP-based services (voice & data, multimedia) has led the wireless industry to evolve its core network towards the IP technology. It is expected that in the near future, IP connectivity will penetrate the access network as well, resulting in an all-IP network concept. A critical aspect for the evolving networks, will be the introduction of a new generation of value-added services, based on innovative personalization and portability concepts (VHE) and in a way that will avoid heavy re-engineering for 3rd party developers. To support such features, new open service architectures and tools (MeXe, OSA) have been proposed, that will enable service providers to exploit transparently the full functionality of existing and forthcoming network infrastructures. In light of the recent and upcoming developments, this paper presents an overview of the aforementioned issues and investigates the synergy between the two major trends (evolution towards an all-IP network and service architecture standardizing open interfaces) leading to new roles and actors' relations in the evolved 3G business models.*

I. INTRODUCTION

UMTS, viewed as the European member of the family of 3G mobile systems within the ITU IMT-2000 framework, is forseen to provide unified access to a multiplicity of services, through advanced low-power terminals and guarantee high capacity to support traffic in a variety of mobile environments. Since mid-1999, UMTS specification has been driven by two major trends, which have greatly influenced all further evolutions of the 3G standards.

The first trend was the shift towards an *all-IP UMTS core network architecture*. This shift replaced the circuit-switched transport technologies used in UMTS R99, by packet switched and introduced multimedia support in the core network. Moreover, outside the official standardisation bodies (i.e. 3GPP, 3GPP2) a number of manufacturers' and operators' fora and partnerships (3G.IP, MWIF), have greatly contributed to the immense level of industrial success of the all-IP network architecture. The second trend was the evolution toward an *open service architecture* (OSA), which obliged network operators to provide 3rd party service providers, access to their UMTS service architecture via open standardised interfaces. These evolutions have led to new business models integrating characteristics of both wireless and wire-line service deployment.

This paper is organised as follows: Section II presents the all-IP network concept, while section III illustrates the service architecture concepts in the evolved networks. Section IV presents the emerging business models and the paper concludes in section V.

II. THE ALL-IP NETWORK CONCEPT

Packet data services typically exhibit highly bursty traffic patterns, demanding fast traffic channel allocation and de-allocation and high peak rate transmission during activity periods, with relatively long periods of inactivity. This is in contrast to the classical circuit voice and data services permitting relatively slow connection set-up and release via a dedicated channel and continuous transmission at constant data rates. 2G wireless core networks are based on circuit-switched SS7 architecture, similar to that found in wire-line communications. Due to the explosive growth of the Internet and the increasing demand for all sorts of IP-based services (Voice / Multi-Media over IP), fast and efficient handling of packet data in 3G wireless networks has become a major issue. The market expects 3G mobile radio networks to provide Quality of Service (QoS) and transmission speed of similar order to fixed wire-line access networks. However, expectations are hard to be met, since available spectrum and transmit power resources in terrestrial and especially in satellite mobile radio are very limited. Nevertheless, future wireless systems are obliged to efficiently deliver packet-oriented services, exploiting the scarce physical resources as best as possible. 3GPP [1] Rel.5 standard[1] is defining a reference architecture for UMTS core networks that comprises 3 domains:

[1] Due to be completed in December 2001

- **Circuit-Switched (CS) Domain**, providing services similar to those provided by current GSM CS voice & supplementary services.
- **Packet-Switched (PS) Domain**, as an evolution of the 2G+ (GPRS) approach.
- **IP Multimedia Domain**, to support IP multimedia applications.

3GPP Network Architecure

3GPP, in evolving to an IP network, has decided to base it on GPRS [2]. The IP-based architecture should support both stream and best-effort services. This implies that the mobile terminal would include IP-based clients. The simplified all-IP architecture is depicted in Figure 1:

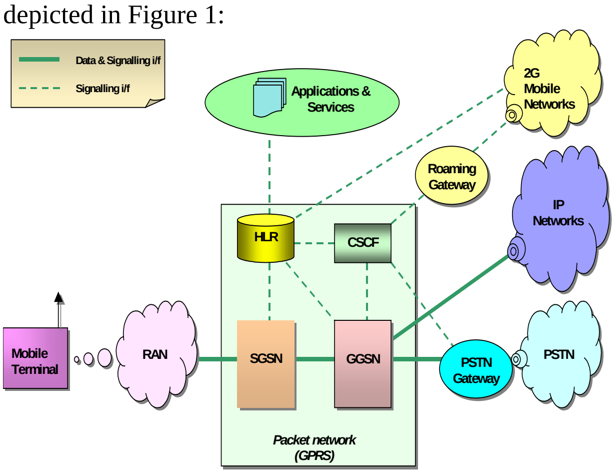

Figure 1: *The 3GPP IP reference architecture*

An essential principle of the above framework was to provide separation between service and connection control. 3GPP essentially started with GPRS as the "core" packet network and overlaid it with call-control and gateway functionality required for supporting VoIP and other multimedia services. This functionality is provided via IETF-developed protocols to maintain compatibility with industry direction regarding all-IP networks. To support VoIP, call control functionality analogous to circuit-switched call control, is provided by the Call State Control Function (CSCF). The MT communicates with the CSCF through the use of SIP protocol. CSCF performs functions such as call control, service switching, address translation and vocoder negotiation. For interfacing to the public switched telephone network (PSTN) and other legacy networks, PSTN gateways are provided. To support roaming to 2G wireless mobile networks, roaming gateway functions are also provided. The GPRS serving node, SGSN, uses existing GSM registration and authentication schemes to verify the identity of the data network user. This makes SGSN access-technology dependent. The GPRS home location register (HLR) is enhanced for services that use IP protocols. The data terminal makes itself known to the packet network by performing a GPRS *attach*. The IP address is anchored in the GPRS gateway node (GGSN) during the entire data session. This limits the mobility of the data terminal within the GPRS-based networks. To provide mobility inter-working with other networks, a foreign agent (FA - as in the IETF Mobile IP) - can be incorporated in the GGSN.

3GPP2 Network Architecture

3GPP2 [3] combines WCDMA radio i/f high data rates and existing work in IETF on Mobile-IP [4], to enhance the network architecture to provide IP capabilities. Globally accepted IETF protocols provide ease of interworking and roaming with other IP networks, as well as access to private networks (VPNetworking), via a Mobile-IP tunnel with security. Figure 2 depicts the 3GPP2 all-IP concept.

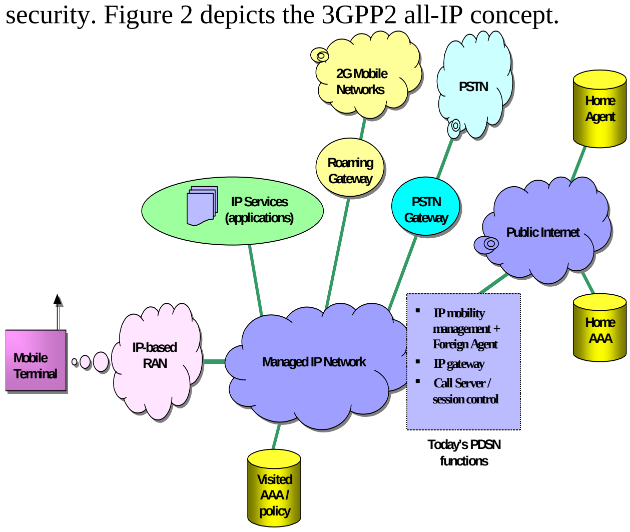

Figure 2:*The 3GPP2 all-IP architecture*

In the 3GPP2 architecture, IP connectivity reaches all the way to the BTS (node B in UTRAN). This means that the BSC (RNC in UTRAN) will be a router-based IP node, containing some critical radio control functions (e.g. power control, soft HO frame selection). The remaining control functions are moved to the managed IP network**.** This includes call / session control, mobility management (IP mobility, FA) and gateway functions (roaming to 2G wireless & interworking with PSTN), thus allowing distributed and modular control architecture.

The functions of the packet data serving node (PDSN) in the 2G today's architecture, are distributed as shown in Figure 2. The MT uses Mobile IP based protocols to identify itself. The PDSN contains FA functionality. When the MT attaches to the FA, the FA establishes a Mobile IP tunnel to the home agent (HA) and through this sends a registration message. The HA accesses the authorization, authentication & accounting (**AAA**) server to authenticate the MT. The IP address of the MT is now anchored in the HA for the duration of the data session. The data device connected to the MT can be handed over to any other access network (wireless, wireline) that supports Mobile IP. Thus, mobility is provided across diverse access networks. However, since Mobile IP essentially uses address translation to provide mobility, due to the latency of address updates between distant agents, fast HO cannot be supported.

There has been considerable research to address the latency issue via schemes such as [5], [6], and [7]. These methods all propose some form of hierarchy with local / gateway routers, which may improve latency by reducing updates from the remote HA.

Convergence of the two approaches

Regarding provision of mobility for IP sessions, the 3GPP and 3GPP2 architectures are different because of the underlying base networks and evolution strategies. In 3GPP, GPRS-based mobility was already defined, so the IP network enhancements were considered on top of GPRS. 3GPP2 needed to develop a mobility mechanism for packet data and decided to use Mobile IP. To illustrate the similarities and differences of the two approaches, mobility needs to be separated into three levels: **Air interface mobility** supports cell-to-cell handover within a radio access network. **Link-level mobility** maintains a Point-to-Point Protocol (PPP) context across multiple radio access networks. **Network-level mobility** provides AAA services across networks.

In both approaches, air i/f mobility being radio specific, is handled in the access network, so harmonization depends on the efforts underway for global CDMA. In 3GPP, link-level mobility is handled by the GPRS Tunneling Protocol (GTP), providing mobility to other 3GPP-defined networks. 3GPP also features an option in which a FA may be located in the GGSN, allowing roaming from GPRS-based networks to other IP-access networks. In 3GPP2, link-level mobility is provided by defining a tunneling protocol as an extension of Mobile IP. Mobile IP architecture allows the mobile to have a point of presence and roam across any IP network.

In 3GPP, AAA for access and data networks are integrated and use the schemes used for wireless. In 3GPP2, AAA for access and data networks are performed separately, i.e. as defined in Mobile IP for a data network. Hence, the data architecture is access-independent. A common set of IP mobility protocols is needed to provide network-level mobility between different access networks, including wireless. IETF is developing a suit of Mobile-IP based protocols to achieve that. The Mobile Wireless Internet Forum (MWIF), begun recently by major global CDMA carriers, intends to drive a single open mobile wireless Internet architecture that enables seamless integration of mobile telephony and Internet services and is independent of access technology. It intends to influence both 3GPP and 3GPP2. Hopefully, cross-forum discussions between 3G.IP, MWIF, 3GPP and 3GPP2 will result in achieving the all-IP objective.

III. SERVICE PROVISION ASPECTS

An major challenge for the evolving networks and the emerging architectures, is the introduction of Value Added Services (VASs) in such a way that will avoid requests for major modifications on well established standards or heavy re-engineering for 3rd party developers. This task becomes trickier if new concepts like the **Virtual Home Environment** (VHE) are to be supported. The concept of the VHE [8] was introduced in 3GPP standardization to ensure that a user will be able to seamlessly enjoy a set of personalized services while moving between different networks or even using different terminals. Obviously, retaining preferences will always depend on the serving network and terminal capabilities.

According to the functional model of the VHE, a user has access to a customized service environment that consists of a set services and a number of user profiles that are activated according to different situations. This environment will be provided and controlled in a well-defined manner by the Home Environment (HE) that has the overall responsibility for the management of user profiles and the provision of the services. Such services can also be provided, transparently to the user, by collaborating with HE VAS Providers.

To support the VHE functionality, new architectures ([9], [10], [11]) and mechanisms [12] have been adopted. The Open Service Architecture (OSA) enables VASPs to exploit the network functionality through open standardised interfaces, while the Mobile Station Application Execution Environment (MExE) provides a comprehensive standardized approach for the delivery of services, applets and content to smart mobile phones.

OSA has been designed to become an intermediate layer between services and the underlying network technology, thus allowing for network-independent services. OSA (Figure 3), consists of the Framework, Service Capabilities Servers (SCSs) & the OSA API.

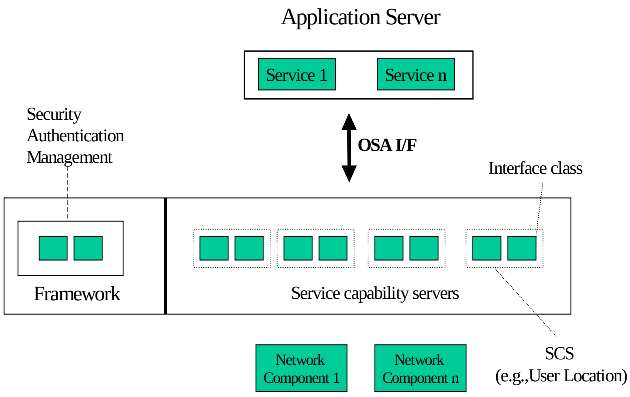

Figure 3: *OSA Architecture*

The Framework handles the authentication and authorisation procedures related to the applications, and registers the features of the SCSs in order to be discovered in the future by the applications. The SCSs are responsible for the mapping of the services' desired functionality to the underlying specific network protocols (e.g., MAP, CAP), hiding the network complexity from VASPs. The functionality provided by the SCSs is grouped into logical classes called Service Capabilities Features (SCFs). Examples of SCFs offered by the SCSs are Call Control and User Location. The OSA service capability features are specified in terms of a number of interface classes and their methods. The interface classes are divided into framework interface classes and network interface classes. Services can exploit the network capabilities by communicating with the SCSs through the OSA API. The OSA caters for security and it has been designed to be scalable and extensible.

MExE provides a standardized application execution environment for mobile devices. These devices use MExE clients to access VASs through a client/server relationship with the MExE servers that reside in the network. The MExE clients can be WAP browsers or Java Virtual Machines. The MExE standard provides for the mobile devices to negotiate their capabilities with the MExE service provider, allowing applications to be developed for small devices with several limitations (bandwidth, displays, limited memory), as well as for devices that can easily support sophisticated applications. To support the wide range of different devices configurations MExE defines three different classmarks:

- MExE classmark 1 is based on WAP and requires limited input and output facilities on the client side. It is designed to provide information access for low bandwidth links.
- MExE classmark 2 is based on Personal Java and supports more sophisticated applications, providing and utilising a run-time system, that requires more processing, storage, display & network resources.
- MExE classmark 3 is based on Connected Limited Device configuration and Mobile Information Device Profile environment, to support Java applications running on resource constrained devices.

MExE enabled devices have to support at least one classmark, while support of multiple classmarks is also feasible. MExE services are transferred between the mobile device and the MExE service environment using standard transport mechanisms (e.g., WAP, HTTP). The MExE service environment may consist of several nodes that provide MExE services while proxy servers (e.g. WAP gateways), that translate content defined in standard internet protocols into wireless optimised derivatives, may also be provided (Figure 4).

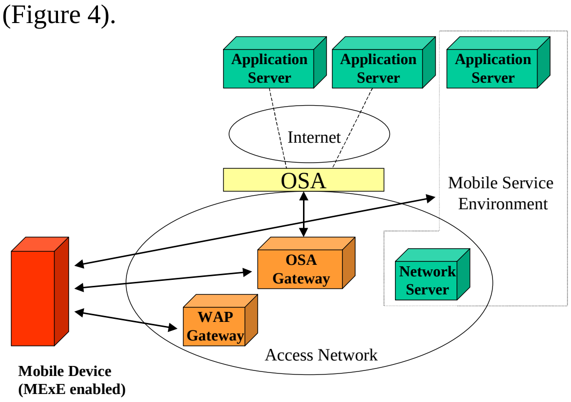

Figure 4: *Overall Architecture*

IV. 3G BUSINESS MODELS

The aforementioned evolutions (i.e., the shift towards IP in the core and access networks and the introduction of new service architectures) and the limited number of 3G operators' licenses, lead in new business models that are gaining ground in the mobile industry. In this new scene new concepts are introduced, namely the Virtual Operators (VOs) and the Wireless Application Service Providers (WASPs).

VOs have access to networks of one or more Mobile Network Operators (MNOs) and offer services to customers using that network. VOs do not have the right to use UMTS radio spectrum. As service creation and low-cost access becomes increasingly important over the next years, VOs will successfully invest in their own infrastructure. This includes investments in mobile devices, SIM cards, switching centers, AAA, OMCs and IN elements. All of these areas provide additional opportunities for suppliers, and thus increase the market potential for areas in which startups are active (e.g. mobile devices, AAA, IP billing systems).

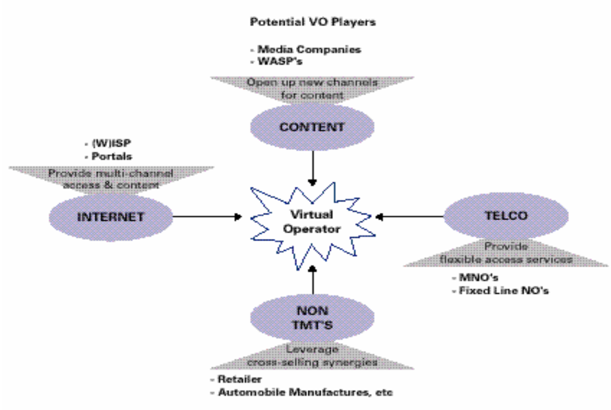

Figure 5: *3G Market VO Players*

Within the context of 3G market, four principal types of new VO players have been identified (Figure 5):

✓ **Content Providers**: including media and entertainment companies looking at mobile devices as an additional distribution channel for their services.

✓ **ISPs & WISPs**: This group (Internet SPs, Wireless ISPs) will implement VO strategies to generate revenues from mobile internet access traffic. This group is also expected to benefit from the 3G all-IP architecture, due to the fact that its backbone architecture can be re-used to deploy such networks.

✓ **Network Operators**: This group includes MNOs and fixed/wireline network operators. Motivations vary. As an example, MNOs will unfold VO strategies to expand their operations abroad. Fixed line operators are interested in complementing their domestic service offerings.

✓ **Non-TMT companies:** will be attracted to the mobile services market for a number of reasons: to leverage existing brands and customer bases, to generate cross-selling opportunities, to avail of a high-volume market, to extend their existing product and/or service range.

The WASP concept provides tremendous opportunities for start-ups, either as a consumer, or as a business WASP. It is expected that MNOs will increasingly facilitate access to their networks for VOs, a trend that will be driven by strong market conditions rather than regulatory forces. This will allow many UMTS NOs (but not all) to successfully exploit the market opportunity. However, it will require MNOs to shift their business focus away from dealing directly with end-users, and allow them to service wholesale clients as well. MNOs that fail to implement such strategies will not survive in the long-term. MNOs in Europe face significant challenges over the next five years. Many of them are investing heavily in UMTS licences and, at the same time, in the rollout of a wide range of new technologies (GPRS, UMTS, WLAN, Bluetooth etc.) that will enable a completely new 'spectrum' of data-oriented services and applications. Traditionally, MNOs have mainly concentrated on the first two issues. Revenues from voice services have driven the vast majority of their existing business in the past, and lured by healthy revenue growth. Developing new services and applications will become a critical success factor in the 3G market. A key question that MNOs have to answer is how they are going to develop the capabilities to exploit the 3G market successfully with partners such as portal players. Partnerships are an appealing option for MNOs where they should start to build organizations in which they treat partners as potential clients. Other reasons for MNOs to move towards open access to their network, include uncertainty about the killer application, huge investments to acquire 3G license spectrum, the desire to maximize capacity utilization, no experience in new service creation market, lack of brand equity and regulatory pressure. WASPs extend the functionality of applications and services to mobile networks. Key reasons why businesses choose to outsource their applications and services to WASPs include time-to-market, risk reduction, lower costs and increased focus. Within the 3G context, many companies will enter this market and they come from different angles including, MNOs, VOs and WASPs. Potential target customers vary widely but will include demand from MNOs, VOs and enterprise customers. A rough segmentation of the WASP market results in two types of WASP players: those that are focussed on enterprise/business users and those that are on consumers. WASPs have a number of revenue streams: licensing, resource usage and share of traffic revenues. Critical success factors for WASPs include billing, integration and partnerships. Based on the multi-channel nature of future digital commerce, consolidation will occur between WASPs and wireline ASPs to offer integrated ASP applications and services. WASPs offering horizontal functionality will align themselves with traditional ASPs offering functional oriented applications ERP and CRM.

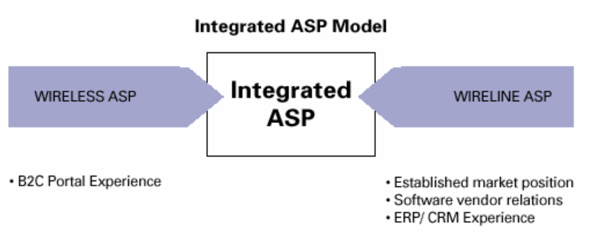

Figure 6: *Integrated ASP Model*

V. CONCLUSIONS

In this paper we have presented an overview of two major trends in 3G evolution. The introduction of the all-IP-network concept has led to the re-design of network components and protocols, merging the connection-oriented & connectionless words, while new service architectures (OSA) and mechanisms (MExE) provide for a flexible deployment of future innovative multimedia services. These evolutions have significant impacts on existing business models. In the new scene new roles like the Virtual Operator and the WASP will create opportunities for start-ups, and will form new coalitions to achieve risk reduction and improved service provision.

VI. REFERENCES

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