FlexiNET: Flexible Network Architecture for Enhanced Access Network Services and Applications

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Abstract— **This paper presents the state of the art in telecommunications and mobile networks, identifies weaknesses in the respective network architectures and defines a scalable network architecture incorporating adequate network elements offering cross-connect control, switching/routing control, and advanced services management/access functions at the network access points that currently only support connectivity between user terminals and network core infrastructures. The proposed network architecture does not replace or enhance existing networking infrastructures, but offers a value-added complementary network architecture addressing service access de-centralisation and separation of data, service logic and control from the pure transport network. This concept is under investigation in the context of FlexiNET (FP6-IST1 507646), a project within the EU IST framework program 6.**

Index Terms—**3G, WLAN, Storage Area Networks (SAN), Dynamic Service Deployment**

I. INTRODUCTION

UP to date, telecommunication networks have been built for specific purposes. For instance, the PSTN/IN network has been built to provide the fixed telephony service, and the mobile networks have been built to support mobile telephony and data services. The aforementioned services run on separate infrastructures. The Internet has been placed on top and (by definition) may use any access and core network technology, but still needs it's own infrastructure to handle subscribers.

The current approach allows only a few players to dominate the market while new services are difficult and effort/cost/time-consuming to introduce due to slow standardisation progress and difficulties to integrate with existing core infrastructures and service implementations. Another major consequence of building 'service-specific' networks is the replication of redundant functions. For instance, one of the functionalities of the Home Location Register (HLR) in mobile networks is subscriber authentication and authorization. If the same subscriber also utilizes an Internet service, this function cannot be reused. Currently, authentication and authorization is set up individually for each service.

Additionally, up-to-date networks use the traditional architectural segmentation of network types in core, access and user-equipment domains, whereby the core network is responsible for "managing" user requirements in terms of switching/routing, bandwidth/QoS reservations, authentication and tariffing, and the access network infrastructure (Local Exchange, Base Station Controller, Network Access Servers, etc) is typically limited to allowing connectivity of the user equipment to the core. Furthermore, existing access infrastructures follow a "monolithic" approach whereby systems are vertically integrated and exhibit low flexibility and customisability.

In this context, network services and even applications offered by "third-party" providers are dependent on, and mainly implemented at the core of the operators' telecommunications networks they deploy. This approach will result, based on future traffic projections, in core-network overload and congestion in terms of access and network-services provisioning.

Therefore, the lack of a novel and consistent approach that would move and/or concentrate interconnectivity (switching/routing), intelligence, dynamic service deployment, and service-management processes towards the edges, is evident. This would enable core networks to be treated as backbone resources being deployed by and interacting with network services and applications.

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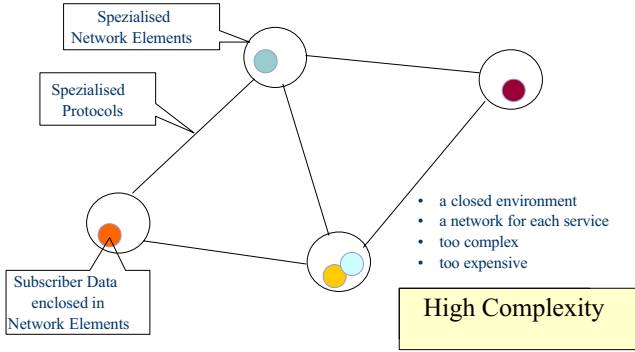
Fig. 1. Telecommunications Networks Today

The purpose of concept presented in this paper is to accelerate the introduction of next-generation marketable services, and increase competitiveness in the telecom field by facilitating the broadening of current business models for services provisioning and exploitation. This will be accomplished by following 5 basic steps, which are presented and analysed in the following section.

II. "FIVE STEPS" BEYOND TRADITIONAL NETWORK ARCHITECTURES

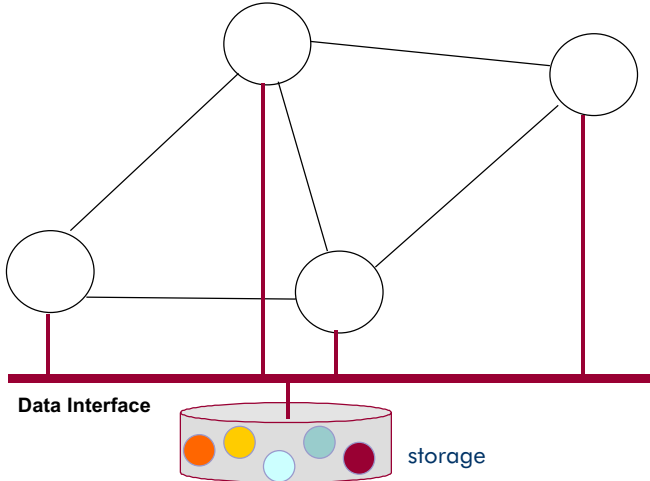### A. STEP 1: GET THE DATA OUT OF THE NETWORK ELEMENTS

Fig. 2. Get the Data out of the Network Elements

Generic Storage Area Networks (SANs) is the solution for the central storage and backup of persistent data kept in various networks elements (HLR, SCP, etc). The approach presented in this paper extends the deployment of SANs also for enabling the rapid introduction and flexible provisioning of applications. In this manner information will be directly available at the access points (FlexiNET Node Instances), while security-related and networks interoperability issues (communications protocols) will be solved through the deployment of widespread and established Internet and Information Technologies. An adequate open common data model will be defined and developed for this purpose addressing the requirements of divergent information and database technologies (RDBMS, ODL, OQL, etc).

B. STEP 2: USE A SERVICE-CENTRIC ARCHITECTURE FOR NEW APPLICATIONS

This framework deploys two main general-purpose communications buses, namely the Applications and Data interfaces, instead of the up-to-date multitude of specialised communications protocols:

1) The Generic Applications Interface comprises a low cost, general purpose and future proof IP-based application-layer bus used for the communication between the various FlexiNET nodes, and allowing the access of core and access network resources by third party application providers.

2) The Generic Data Interface provides uniform access to the applications data residing in the generic Storage Area Networks.
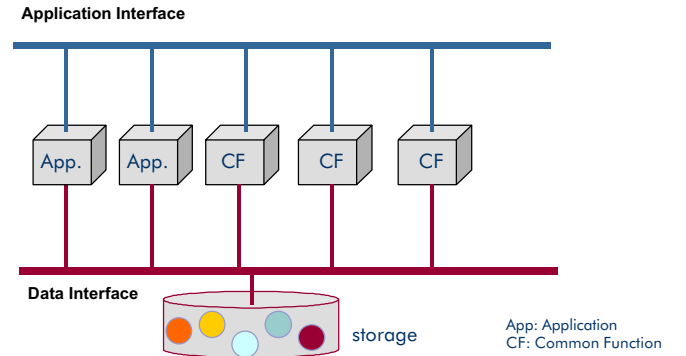

Fig. 3. Use a Service-Centric Architecture for new Applications

This architecture also allows for re-use of Common Functions by applications, in order to eliminate duplication of the actions performed e.g. for authentication, authorisation, etc, across different network and services.
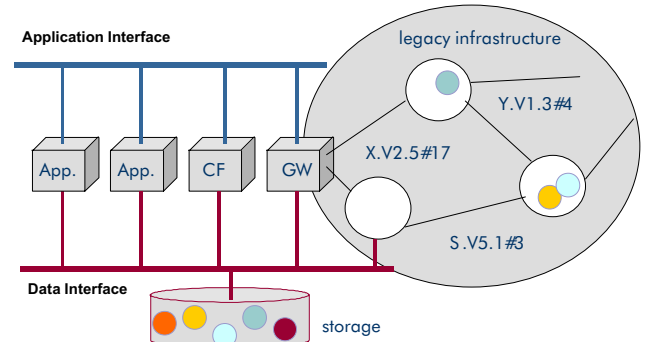
C. STEP 3: INTEGRATE LEGACY INFRASTRUCTURE

Fig. 4. Integrate Legacy Infrastructure

The integration of legacy infrastructure within the novel framework aims at preserving existing operators' investments and in the same time enable the rapid realisation of new revenue generating services. This will be accomplished by defining and implementing the procedures and communications interfaces enabling the management of legacy networks resources and retrieval/updates of applications information currently 'hidden' in a wide variety of network elements.

D. STEP 4: MOVE SWITCHING, AND SERVICES MANAGEMENT TOWARDS THE NETWORKS EDGES

As core networks operation become more complex due to the constantly increasing number of services and applications support over existing protocol stacks, interfaces and functionality duplication is unavoidable to achieve improved performance and cope with protocol incompatibilities especially on the signalling domain.
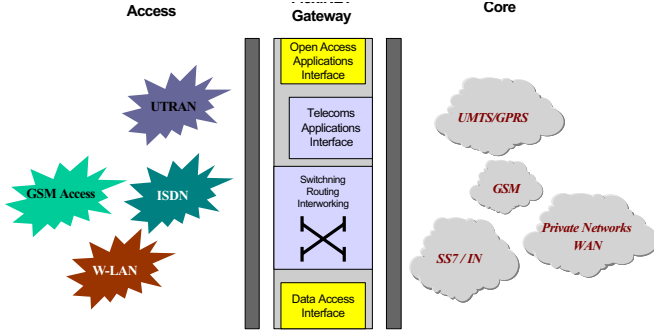

Fig. 5. Move Switching, and Services Management towards the Networks Edges

The proposed network architecture is based on gateway platforms, which through the introduction of WANs making use of generic applications and data interfaces, will perform the operation of accessing network elements (RNC, BSC, WLAN access point). Furthermore, the FlexiNET Node Instances incorporate core network functionality (routing tables for switching/routing, access to generic SAN and network databases, access to third-party applications providers, etc), which up-to-date were implemented as separated building blocks on the core networks and backbones.

The access network functionality will be available on every networking element block at the same time, through WAN interfaces, thus eliminating circulation of unnecessary traffic on the user communication interfaces. Under this scheme, the proposed network architecture provides the means of realising an alternative network architecture allowing optimum bandwidth utilisation and reasonable network resources management leading to considerably improved performance in user data manipulation.

E. STEP 5: DYNAMIC SERVICE DEPLOYMENT

The proposed network architecture advocates the separation of control and service logic from the transport network and supports it by means of open Application and Generic Interfaces (see Step 2). The proposed network architecture also advocates the capability of the on-demand deployment of such interfaces and the services they represent. With on-demand service deployment novel services may be added extending the functionality of network elements, and thus the network, while existing ones may be upgraded or further customised. These actions are performed at run time, thus reducing the operational cost of the network, and supporting its future-proof operation. Accordingly, the proposed network architecture introduces the necessary mechanisms for the dynamic

deployment of services and their components.

III. THE PROPOSED NETWORK ARCHITECTURE

The network architecture offers a complementary network architecture to the existing networking infrastructures of UMTS and WLAN, which provides cross-connect control, switching/routing control and advanced services functions at the network access points. Figure 6 depicts an overview of the proposed network architecture, which consists mainly of node instances, communication buses and data repositories.
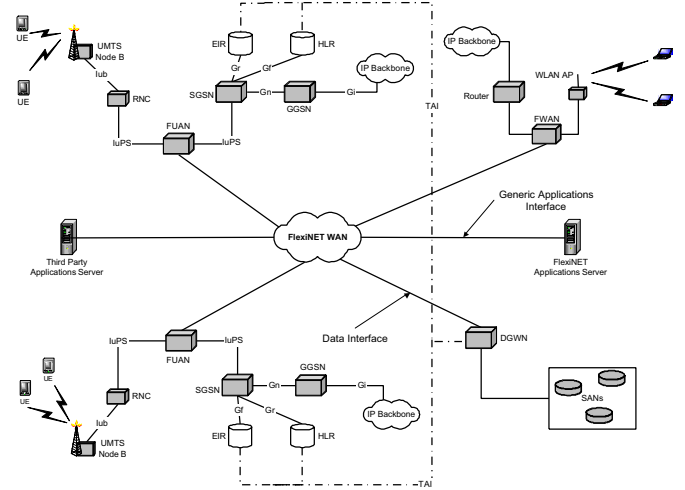

Fig. 6. Overview of the proposed network architecture

The **FlexiNET UMTS Access Node (FUAN)** brings to the network architecture interfaces, functions such as switching/routing control, access to applications data & service logic, etc. The FUAN complements existing access nodes (RNC, BSC). This is achieved through the provision of adequate interfaces connecting a traditional access network switch (e.g. RNC) with the FlexiNET added value network. The FUAN also implements the required Applications & Data Interfaces for accessing the other FlexiNET elements.

The **FlexiNET WLAN Access Node (FWAN)** acts as both a services access gateway (user authentication, service authorization, service discovery, etc.), and connection gateway between WLAN infrastructures and the FlexiNET WAN. Signalling interworking with the UMTS subscriber data is implemented mainly for authentication, authorization, accounting, and context retrieval purposes. This network element implements fully the FlexiNET architecture of dynamic service deployment components spanning applications-related functions (e.g. transcoding, authentication, authorization, etc) as well as underlying transport/network services (routing, signaling, QoS provisions, etc).

The **FlexiNET Data Gateway Node (DGWN)** acts as the Gateway between the generic SAN infrastructures and the other network architecture allowing for the realisation of the data-centric services approach. It is used by other FlexiNET node instances for accessing subscriber (profile, location, etc) & applications data required for services

execution. It provides a Generic Data Interface, which other network elements may use for accessing the stored data in the SANs.

The **Generic Applications Interface Bus** is the central and most important mechanism for the interconnection of the FlexiNET node instances. This is used for the implementation of dynamic application-related functions (e.g. subscriber management, service control, context retrieval, connection through an Enterprise Application Interface-EAI to conventional systems like billing, ERP systems, etc.) and the communication of information flows pertaining to the execution of application and service logic, including a framework allowing service registration, discovery and binding.

The FlexiNET Applications Server (FLAS) is the physical entity, which hosts the logic of the applications that the FlexiNET network architecture provides. These applications - can be also called services - are called from other entities remotely and executed locally. Using the DGWN they are in position to retrieve specific information needed for services execution. The FLAS also allows the dynamic deployment of new services and components. The OSGi service platform is used for this purpose.

The **Interworking Bus with Legacy Switch Platforms** provides adequate interfaces connecting a traditional access network switch (e.g. RNC) with the FlexiNET node hardware platforms. This Interworking Bus includes where required the Telecommunications Applications Interface, which connects to legacy switching platforms and core network infrastructures (EIR, HLR, etc.) using standard signalling interfaces (MAP, BSSAP, etc).

As far as data repositories are concerned, generic **Storage Area Networks** infrastructures making persistent applications data (e.g. subscription information, billing information, user profiles, etc) – which are currently enclosed in networks (HLR, HSS, SCP, EIR, etc) – available across the proposed network architecture buses.

IV. FLEXINET EVALUATION USER SCENARIO

FlexiNET Evaluation User Scenario refers to the access of a Web server via the UMTS network complemented with the FlexiNET network architecture, using a notebook with UMTS access capabilities. The network configuration for the FlexiNET user scenario is depicted in the following figure.
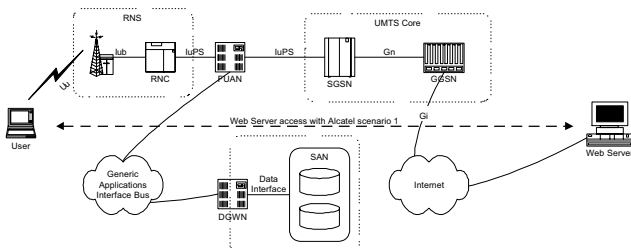

Fig.7. Network configuration for FlexiNET user scenario

In this scenario, a FlexiNET UMTS Access Node (FUAN) and a FlexiNET Data Gateway Node (DGWN) will be used. The FUAN is a gateway node between the RNC and the SGSN providing access to the Storage Area Network (SAN) via the DGWN. The FUAN will be used for handling switching and routing functions, while the DGWN provides access to the subscriber data required for services execution.

Firstly, the user connects to UMTS network and the GPRS attach takes place. The MSC for the GPRS attach concerning the FlexiNET user scenario is depicted in the following figure.
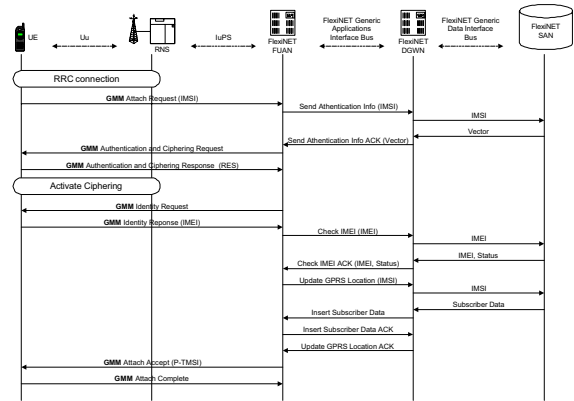

Fig. 8. FlexiNET GPRS attach for the User scenario

The GPRS attach is initiated by UE and has 3 phases:

1. An RRC connection is established between UE and RNC. A Request of a GPRS attach initiated by UE is being sent to FUAN.

2. FUAN authenticates the identity of the user and equipment. The data exchanging will be ciphered.

3. FUAN address will be registered in SAN. FUAN gets the services, which the UE can use from SAN and UE gets the P- TMSI.

The MAP messages exchanged between the SGSN and the HLR during GPRS attach at the traditional UMTS network, are replaced with messages exchanged between FUAN and DGWN via the Generic Applications Interface Bus. The DGWN is responsible for retrieving information from SAN in order to be sent to FUAN.

The GPRS attach will be rejected by FUAN, if the IMEI or IMSI are invalid. Later registration will be impossible. Upon the completion of the GPRS attach, the user has been authenticated and the UE knows the PMM state and the P-TMSI. The FUAN knows the PMM state, the P-TMSI, the MSISDN, the RA, the KSI (IK, CK) and the QoS profile. Finally, the DGWN is aware of the FUAN address.

The user will be able to receive or transmit data via the UMTS network after the completion of the PDP context activation procedure. The MSC for the PDP context activation concerning the FlexiNET user scenario is depicted in the following figure.
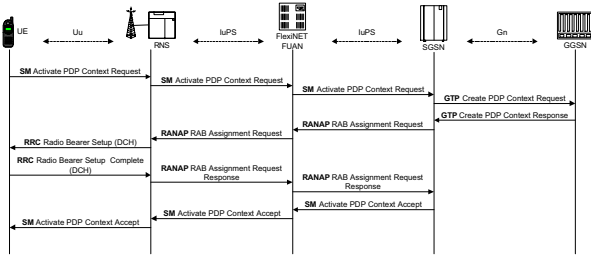
Fig.9. FlexiNET PDP context activation for the User scenario

The UE sends an Activate PDP Context Request (NSAPI, TI, PDP Type, PDP Address, Access Point Name, QoS Requested, PDP Configuration Options) message to the SGSN via FUAN. The UE shall use PDP Address to indicate whether it requires the use of a static PDP address or whether it requires the use of a dynamic PDP address. The UE shall leave PDP Address empty to request a dynamic PDP address. The SGSN validates the Activate PDP Context Request using PDP Type (optional), PDP Address (optional), and Access Point Name (optional) provided by the UE and the PDP context subscription records.

The SGSN sends a Create PDP Context Request (PDP Type, PDP Address, Access Point Name, QoS Negotiated, TEID, NSAPI, MSISDN, Selection Mode, Charging Characteristics, Trace Reference, Trace Type, Trigger Id, OMC Identity, PDP Configuration Options) message to the affected GGSN. The GGSN creates a new entry in its PDP context table and generates a Charging Id. The new entry allows the GGSN to route PDP PDUs between the SGSN and the external PDP network, and to start charging.

The GGSN then returns a Create PDP Context Response (TEID, PDP Address, PDP Configuration Options, QoS Negotiated, Charging Id, Cause) message to the SGSN. PDP Address is included if the GGSN allocated a PDP address. The SGSN inserts the NSAPI along with the GGSN address in its PDP context. If the UE has requested a dynamic address, the PDP address received from the GGSN is inserted in the PDP context. The SGSN selects Radio Priority and Packet Flow Id based on QoS Negotiated, and returns an Activate PDP Context Accept (PDP Type, PDP Address, TI, QoS Negotiated, Radio Priority, Packet Flow Id, PDP Configuration Options) message to the UE. The SGSN is now able to route PDP PDUs between the GGSN and the UE, and to start charging.

The User is now able to access the Web page from the Web server via the UMTS network complemented with the FlexiNET network architecture.

If the user wishes to terminate its access to the UMTS services, the closing session takes place. The MSC for the closing session concerning the FlexiNET user scenario is depicted in the following figure.
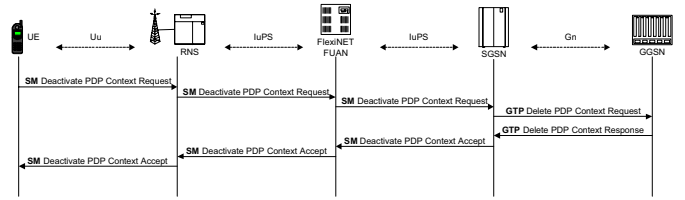

Fig. 10. FlexiNET closing session for the User scenario

The UE sends a Deactivate PDP Context Request (TI, Teardown Ind) message to the SGSN via FUAN.
The SGSN sends a Delete PDP Context Request (TEID, NSAPI, Teardown Ind) message to the GGSN. If the UE in the Deactivate PDP Context Request message included Teardown Ind, then the SGSN deactivates all PDP contexts associated with this PDP address by including Teardown Ind in the Delete PDP Context Request message.

The GGSN removes the PDP context(s) and returns a Delete PDP Context Response (TEID) message to the SGSN. If the UE was using a dynamic PDP address allocated by the GGSN, and if the context being deactivated is the last PDP context associated with this PDP address, then the GGSN releases this PDP address and makes it available for subsequent activation by other UEs. The Delete PDP Context messages are sent over the backbone network.

Upon the completion of the PDP context deactivation procedure, the GPRS detach takes place. The MSC for the GPRS detach procedure concerning the FlexiNET user scenario is depicted in the following figure.
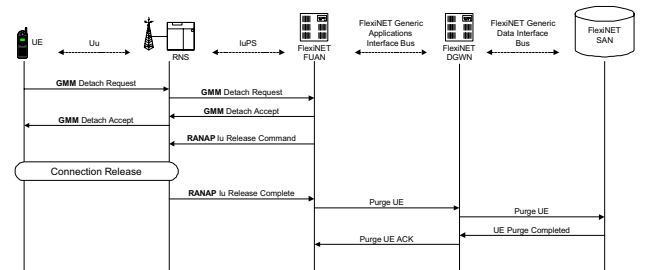

Fig. 11. FlexiNET GPRS detach for the User scenario

The UE detaches by sending Detach Request (Detach Type, P-TMSI, P-TMSI Signature, Switch Off) to the FUAN. The Detach Request message includes P-TMSI and P-TMSI Signature. P-TMSI Signature is used to check the validity of the Detach Request message.

After that, the Purge function takes place. The Purge function allows the FUAN to inform the SAN that it has deleted the MM and PDP contexts of a detached UE. The FUAN deletes the MM and PDP contexts of an UE immediately after the implicit or explicit detach of the UE.

After deleting the MM and PDP contexts of a detached UE, the FUAN sends a Purge UE (IMSI) message to the SAN. The SAN sets the UE Purged for GPRS flag and acknowledges with a Purge UE Ack message.

V. EVALUATION APPROACH

The FlexiNET network architecture will be initially assessed and evaluated against the following criteria:
- Reduction of the circulation of signalling information to retrieve subscriber data and network parameters from databases.

- Dynamic service deployment and configuration capabilities in the FlexiNET node instances.
- Openness of the FlexiNET applications to third party application providers.
- Provision of central data repositories to avoid duplicated logic.
- Reduction of operational costs for maintenance, administration and future expansion.

In order to assess and evaluate the extra network capacity gained with FlexiNET architecture, throughout trials experimentation phase, test configurations will also be carried out with a view to provide measurable evidence on:

- The increase of beneficial line bandwidth through traffic decongestion on the access nodes.
- The number of supported users. This parameter can be measured by the BHCA (Busy Hours Call Attempts), showing how many users a node may administer over hourly periods.
- Guarantee of QoS. It can be measured by observing the user packet delays fluctuation in direct proportion to overall line bandwidth utilisation.
- Minimisation of communication malfunctions. Network malfunctions can be measured at high level with parameters such as service denial and at lower level, with loss of packets and individual protocol errors.

Will be also shown that with FlexiNET, performance degradation can be caused only by factors not related to the context of a call and the number of supported users and will not be a function of time.

Quantitative insight in the performance benefit offered by the FlexiNET architecture, can be only achieved through the cascading of emulators on the interfaces implementing the communication between the core and the access network. To do so, specific FlexiNET platform configuration will be "scaled up" with the introduction of test equipment at specific network branches to measure the aforementioned performance parameters. Testing systems can be used as:

- Monitoring devices, tracing the traffic shape over the time.
- Traffic analysers, measuring the QoS (e.g. packets delay over Iu/Gi/Gn).
- Users emulator, where the system replaces a network branch (for example, the branch consisting of the RNC, NodeB and the mobile subscriber, as indicated in the figure below) and emulates it so that to measure network performance with controllable initial parameters (i.e. number of active users, specific QoS values, etc).

Specifically, with the emulation capability, the following measurements can be taken:

- BHCAs: How many users the network can accept.
- Bandwidth capacity: What is the maximum beneficial bandwidth per link and how its value changes over the time.
- Load & Stress: Observe QoS guarantee.
- Conformance test: Test network signalling procedures integrity under the new communication scheme.

VI. CONCLUSIONS

The purpose of this paper is to define a scalable and modular network architecture incorporating adequate network elements (FlexiNET Node Instances) offering cross-connect control, switching/routing control, and advanced services management/access functions at the network access points that currently only support connectivity between user terminals and network core infrastructures.

The primary aim is not to replace or enhance existing networking infrastructures, but to offer a value-added complementary network architecture addressing service access de-centralisation and separation of data, service logic and control from the pure transport network. The proposed architecture will be based on the FlexiNET node instances, which will consist of scalable hardware and software platforms on top of which core network functionality will be realized, as a set of distributed sub-systems integrated into a generic services execution environment. The paper concepts and architecture are applicable to various access network technologies (GSM/GPRS/UMTS, WLANs, V5, etc.), but are focused on the mobile and wireless operator needs (UMTS & WLAN) for packet switched applications.

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