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A MULTI-MODE HOME NODE-B AIR INTERFACE PROTOCOL STACK MODEL: AN OPPORTUNITY FOR AFRICAN COUNTRIES

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Abstract: Home Node B system as an aspect of a small cell system can be further explored into more opportunities. This paper presents a more flexible home NodeB model mostly for developing countries that can accommodate voice transmission platform. It showed that for a deployed system of such, operators of developing countries can manage resources effectively, and easily extend macrocell coverage of their voice transmission with value added quality of service to their subscribers. The workability of the model was demonstrated using algorithms, and the routers connectivity simulation result recorded a success rate in nodes connectivity.

Keywords: Communication; Frame Relay Protocol Home NodeB; Multi-mode Home NodeB; Radio Waves

I. INTRODUCTION

It is true that the advent of mobile communication in Africa has outpaced its expectation in just a period of 15years, but a lot of work needs to be done to put Africa in a competitive platform with other continents like Europe and North America in terms of service delivery. This is true because some of the innovations in the world of mobile communication like small cell system have been down-played by most African countries simply because, our telecommunication firms have concluded within their own reasoning that the macro cell deployment should bring more profit and so micro cell deployment is not worth giving attention. However, a coexistence of both will not only benefit operators but will benefit subscribers through enriching the operator's quality of service. It is also important that operators' attention should not only be focused on profit alone, but should also accommodate providing the best quality of service. In view of the aforementioned issue with Africa, this study focused on bringing to light the need to embrace small cell technologies and also presenting a better small cell technology using the existing Home NodeB System as a case study. The existing HNB of Universal Mobile Telecommunication System (UMTS) is a static technology and thus cannot accommodate any other generation technology. In order for a Home NodeB to benefit developing countries, it should be more robust and dynamic to accommodate even lower generation technology. Also, studies indicated that the widely used cellular technologies in developing countries under European cellular standards are Global System for Mobile communication (GSM) and UMTS. UMTS is a technology that came as an improvement on some of the gaps noticed with GSM such as security gap, data bandwidth limitation and its inability of embarking on video calls. A country embarking on UMTS technology must be faced with the challenge of diluted indoor signal thus the need for an indoor booster as mentioned above. Once HNB is deployed in an area, GSM users around the vicinity who are out of GSM signal coverage but under the coverage of HNB cannot place calls or access data through it. The aim of this study is to develop an adaptable Multi-mode HNB air-interface protocol stack model that will accommodate more subscribers simultaneously and also accommodate GSM users so described. This study looks at proposing a more robust HNB as a small cell structure that will be cost effective in the sense that, already existing technologies will still be in place while maintaining an improved quality of service in the area of decongestion, smoother handover and co-existence of different generation technologies simultaneously. The rest of the paper is organized as follows: Review of related works, Multi-mode Home Node-B concept and MHNB close user group connectivity.

II. LITERATURE REVIEW

A good number of articles related to small-cell base station have been presented in the areas of interference mitigation among deployed small cells, economic benefits of the system to cellular operators and users, congestion controls, many use cases and managements. In [7], a proposed cognitive small cell that will be able to handle user offloading and also be able to offer a distributed channel access technique was presented and its usefulness to cellular technology discussed. In [14], a cognitive radio that would be able to enhance interference coordination for femto cell networks was envisioned and presented to show better performance in handling cross-tier interference coordination with benchmarked with existing techniques. In [2], the performance and deployment of various small cells (pico, femtocell) from past, present and future was examined, and their economic and capacity benefits were highlighted.

In [5], a hierarchical architecture and manual cell planning processes of macrocell, as not being an effective practice in the deployment of millions of femtocell was envisioned. They proposed the deployment of femtocells using a base station router (BSR) flat Internet Protocol (IP) cellular architecture, which they reported as having some financial advantage in its deployment. In [10], the researchers looked at interference mitigation where two interference mitigation strategies that femtocell users could use to adjust their maximum transmission power were proposed as an open and closed-loop techniques and were used to determine the Signal-to-Interference-and-Noise Ratio (SINR) of a particular transmission and the broadcast information on the average power level of the noise. In [4], the uplink capacity analysis and interference avoidance strategy for a Code Division Multiple Access two-tier cellular network was envisioned. Their work employed a stochastic geometry framework for modelling the random spatial distribution of users/femtocells and also reported a frequency reuse technique that should offer better interference avoidance. In [11], the impact of the complex interplay of interference and service pricing on user's adoption of femtocells was investigated. The researchers modelled a monopolist wireless network operator, offering two mobile service options to a population of users with a fixed amount of spectrum for deployment. Their result showed that the optimal pricing scheme always charges a higher price for the femtocell service. Also, if the degradation coefficient is sufficiently low, revenues from the common spectrum are always higher than that with the split spectrum scheme[11]. In [9], the researchers proffered a self-organizing approach for frequency assignment within femtocells. In order to propose the self-organization approaches, the researchers employed a method based on broadcast message (where the femtocell estimates the probability of usage and interference intensity) and measurement reports sent from a user to the serving femtocell. Dynamic system-level simulations confirmed that their methods may improve user's throughput by around 26% and 34% respectively compared to the random assignment [9]. Also, an efficient resource assignment algorithm must consider circumstances at the user environment in order to efficiently mitigate interference as well as the behaviour of the traffic[9].

III. MULTI-MODE HOME NODE-B AIR INTERFACE ARCHITECTURE, TECHNIQUE AND OPERATION

Research has shown that operators in developing countries are using more than one generation technology in their operation where GSM is still been used for voice transmission while higher generation technologies are been dedicated to data transmission [1].

Multi-mode Home Node-B (MHNB) is a technology that is meant to incorporate more than one air-interface protocol stack into one device. MHNB technology should also offer better performance as compared to the existing HNB, in terms of speed, coverage distance and capacity.

The concept is meant to address the inability of existing HNB to accommodate more than one air-interface protocol stack. The essence of such technology is to enable telecommunication firms in developing countries that are still carrying their voice services with GSM, to also benefit from the deployment of MHNB, through extending the GSM service to areas that are not within the reach of the GSM coverage, but within the reach of MHNB (figure 1, illustrates a scenario involving GSM deployment and MHNB deployment where, the signal coverage of MHNB extends to the GSM uncovered area).

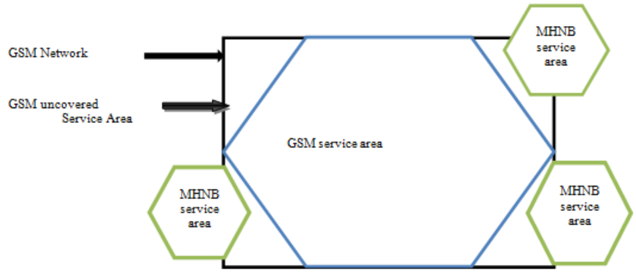

Figure 1: Illustration of GSM deployment and MHNB deployment

In figure 1, the spaces between black and blue border, represent the uncovered service area of GSM network. The space within the blue hexagonal shape represents the service area of GSM network while the light green hexagonal shape represents the service area of the MHNB. A user migrating from the service area of GSM network to the service area of the MHNB automatically will be handed over to the services of MHNB thus, retaining its access to GSM services.

The MHNB proposed technology could be achieved by integration of the *Uu* interface and Um interface into an IP network, while the *luh* interface will be integrated along with the *Abis* interface in what will be known as MHNB gateway. The IP network was achieved using high end routers and will replace HNB device (see figure 2, for the block architecture of a MHNB system).

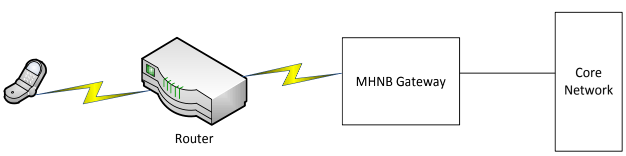

Figure2: Block Architecture of MHNB System

The access network of MHNB that is from either UE to the MHNB was made to be carried over an IP network where the subscriber's identity, identified by the network prefix was mapped to various subnets created from the router's network address (see algorithm below).

Algorithm showing how the subscriber identity should be mapped to router's subnet addresses:

{
  Let I = 2^y /* Incremental value*/
    Let M = (2^y -1) - 2 /*allowed number of users*/
      N = number of users required by the operator
Assumption
      start last octet of IP from 0
Initialization
 Step 1: IP = 0 ; x = 1 to N
 {
 Step 2: Do
 Step 3: IP++
 Step 4: Where IP < (xI) - 1
Step 5: Append IP to (UMTS/GSM/any other technology) a particular operator's network prefix as part of the CSG }
More required for another generation technology
{
Step 6: IP += 2
Step 7: IP++
Step 8: Go to step 4
Step 9: Repeat step 5 while using the new set of generated subnet
More required for another generation technology
Step 10: Do
Step 11: Step 6 and step 7
Step 12: Repeat step 4 and step 9
End

The algorithm will first calculate the router's IP subnets then, translate the subscriber's identity into the various created router's subnets. A router will use this procedure to transmit the air-interface protocols of the user to the MHNB, which performs the un-wrapping operation for identification of the generation technology before directing access to the appropriate channel. The operation of the proposed MHNB system at the MHNB controller was achieved using an Access Mode Switch. The Access Mode Switch will enable a toggle between the GSM access network protocols and the UMTS access network protocols (see algorithm at the MHNB controller showing its operation and figure 3,for the access mode switching at the MHNB controller)

Algorithm at the MHNB Controller

{
  Received packet from router?
    Yes
      Then un-wrap IP packet
        Compare access protocol with the defined ones
}
 {
If protocol = GSM access protocol
    Switch to the left using access switch }
 {
 Else
  If protocol = UMTS access protocol
    Switch to the right using access switch }

{
Else
    Protocol not GSM or UMTS
      Block access }
End
 }

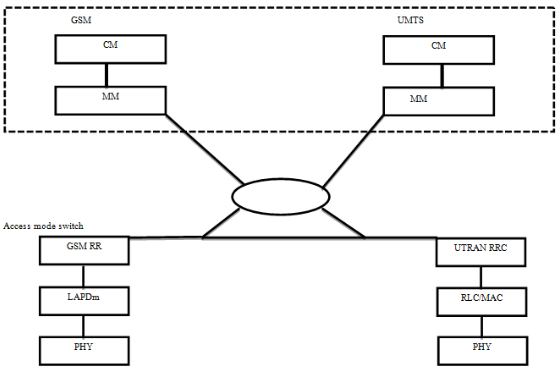

Figure 3: Access Mode Switching of MHNB (protocols adapted from [11] and [12]

IV. MHNB CLOSE USER GROUP CONNECTIVITY

The interconnection of various routers serving each close user group of MHNB is achieved using frame relay protocol. Frame Relay Protocol is one of the concepts emerged from the need for a packet switched network. In this study, it was used to enable connectivity among routers serving each close user group when deployed.

The frame relay algorithm as presented below was implemented using Graphical Network Simulator 3 (GNS3) platform. It also supports Asynchronous Transfer Mode (ATM)/Frame Relay switches and hubs [3]. The configuration comprised of three routers (number of deployed routers is dependent of the operators requirement), deployed separately within the same network (see figure 5, for the configuration setting of three different location routers within the same network), where each router was used to breach the distance between the mobile and the MHNB controller/gateway.
Algorithm for the frame relay configuration

#Router1

Step 1: Activate Interface

Step 2: Assign IP identity to interface

Step 3: Enable frame relay encapsulation using the keyword “encapsulate frame-relay”

Step 4: Map router’s interface identity to the corresponding “Data Link Connection Identifier Number”

Step 5: Shut-down auto-mapping using the keyword “no frame-relay inverse-arp”

Step 6: Shut the interface

End.

#Router2

Perform Step1 above

Assign a different IP id but within the same network as in 2 above

Repeat Steps 3,4,5 and 6 above

End.

#Router3

Perform Step1 again

Assign a different IP id but within the same network as in 2 above

Repeat Steps 3,4,5 and 6 again

End.

A more comprehensive illustration showing the MHNB architecture as deployed infigure 2and their interconnection to the core network and other cellular networks is shown in figure 6.

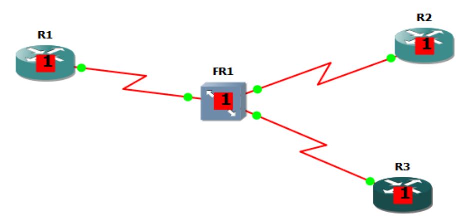

Figure 5: Configuration setting of three different location routers within the same Network

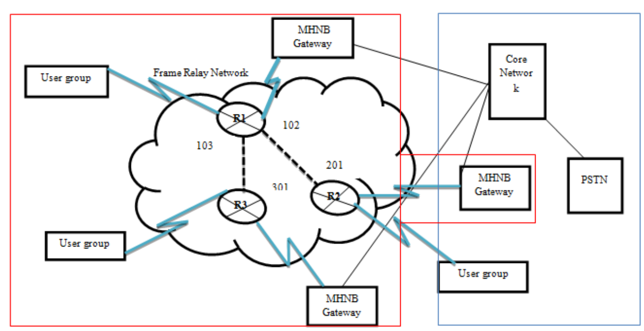

Figure 6: Interconnection between MHNB Network, Core Network and other Public Switch Telephone Network (PSTN).

In figure 6, the areas with red square is the adaptable proposed model while the cloud represents the frame relay network implemented to connect the three routers together. This will enable communication within different close user groups within the same network. R1, R2 and R3 communicate with each using DLCI number thus forming virtual link (represented with dotted lines) among the three routers.

MHNB Gateway acts as the MHNB network controller and forms the middleman between the core network and the close user group. It takes the role of Radio Network

Controller /Base Station Controller. The link between the MHNB Gateway and the Core network is wired link and so also the link between the Core network and the PSTN. The PSTN connection with the Core network provides access to other cellular networks. The other connections as shown in figure 6 also, were achieved using wireless link (represented using blue lines). The configuration of Router1 (R1) took a point-to-multipoint point connection. This is because it serves as Hub to both R2 and R3. R2 and R3 were configured as a point-to-point connection to R1. R1 is a hub because communication between R2 and R3 is achieved through R1. The major reason behind this configuration format is to effectively manage bandwidth resources. Other configuration format can also be adopted (like making each router point-to-point) depending on the aim of the operator and the MHNB gateway can also accommodate more than one router.

V. MODEL EVALUATION

The study was evaluated against the existing system using the parameters listed in the table below:

Table 1
Evaluation of the existing system and the proposed system

Metrics	Existing System	Proposed System
Bandwidth	Use of WCDMA as multiple access technique to manage resources. Peculiar to only one cellular technology	Allows shared pool of bandwidth for more than one cellular technology
Traffic Control	Controls traffic using capacity threshold	Provides means for traffic shaping using Committed Information Rate (CIR)
Success Rate	Determine by HNB device signal strength	Determine by the DLCI number mapping
Scalability	Accommodates small number of subscribers (1-4) as its CSG and cannot take additional number.	Scalable and can benefit multiple generation technology due to the use of IP access network for synchronization
Flexibility	Operators use HNB device based on manufacturers direction	The keyword “Broadcast” is used to enforce broadcast traffic as a way to forward routing update to other routers.

VI. CONCLUSION

In conclusion, it was observed that less attention was paid on how the existing HNB could have been improved in order to benefit operators in developing countries, as the major focus of the 3GPP has been on the developed countries. Also, the design of the existing HNB was confined within a small number of users without any room for more scalability, should the need arise. The cellular world should be such that any design or improvement has to benefit both developed and developing countries. In essence, this study has presented a new frontier to the existing HNB that will benefit both developed and developing countries.

RECOMMENDATIONS

This research is recommended to the 3GPP committee, for the improvement of the existing HNB. This will help not to limit the benefit to only developed countries but will also benefit operators in developing countries through managing their resources and extension of their network coverage without any huge monetary involvement. It will also benefit users through reduction in the tariff of using the cellular network.

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