3G Intra Circle Roaming Implementation Techniques

R Adityan[1], Phaniram Sayapaneni[1]
[1]Department of Electronics and Communication Engg.,
School of EEE, SASTRA University
Thanjavur, Taminadu, India
s.phaniram1@gmail.com

V Elamaran[2] and Ritesh A Agarwal[3]
[2]Assistant Professor, Dept., of ECE, SEEE,
SASTRA University, Thanjavur, India.
[3]General Manager, RF Network Planning, Reliance
Communications Ltd., Navi Mumbai, India.

***Abstract*— The Current Telecom Industry faces a steady competition of providing new technologies to its customers and to meet the challenges of the up-gradation of the existing technologies. The more the number of operators, the more is the need for spectrum resources as well as new infrastructure keeping in mind the scarce resources available. This report provides a technical analysis of how 3rd Generation (3G) Intra Circle Roaming agreement is done between two operators under a licensed circle subjected to the conditions of the government and the telecom regulatory. Intra Circle Roaming (ICR) is a service which enables a mobile station of a given public land mobile network (PLMN) to offer services from an another PLMN in the same country on a location area basis, with automatic return to the home PLMN. The general idea of this report includes how a basic call, Short Message Service (SMS) and Packet Data Protocol (PDP) activation is made while the subscriber is roaming under ICR considerations with certain requirements from the roaming partner.**

Keywords—3G network; ICR; PLMN; Roaming

I. INTRODUCTION

Wireless technology has an important role in communications even though wired networking through fiber optics and cables has many advantages. The mobile communication world now adopting towards the effective improvisation of data rates has led to the success of the networking throughout the world. Mobile phones are now built with advanced features to cope up with the current standards of the wireless technology [1] [2]. The telecom operators face the challenge of upgrading of the existing technology to meet up with the new technology and increasing growth of subscribers. Market analysis suggests that voice communication still remains the bread and butter for the industry [3].

Roaming is defined as the ability for a mobile subscriber to receive and dial calls, make internet PDP contexts, send or receive messages or access services while travelling outside the Home Public Land Mobile Network utilizing the visited operator network resources. National roaming and international roaming are the two types of roaming in general [4].

By the visited network information, if the visited PLMN (VPLMN) is in the same country as the home network it is called National roaming service and if the VPLMN is in different country it is called International Roaming service [5]. The Mobile Station (MS) utilizes the VPLMN resources of another operator whom the home network has made a roaming pact only when the user is in roaming mode.

Intra Circle Roaming is a type of national roaming where the roaming pact is assigned between operators of same licensed circle thus reducing the roaming charges applicable on customers and thereby improving coverage area of seeker operator and flexibility of selective registration. 3 Hz TO 300 GHz radio frequencies are generally part of the electromagnetic spectrum which is strongly regulated by the government in most of the countries in co-ordination with International Telecommunication Union (ITU) [6].

Spectrum Resources allotted to each service provider are becoming exhausted due to new technology inventions and the ever growing subscribers. One such case is the spectrum auction where operators could get only few states for broadcast and services [7]. A methodology to effectively utilize the spectrum is by Intra Circle Roaming. Intra Circle Roaming is a technique to improve efficiency of a network provider services by allowing the subscriber to use another network provider's PLMN resources within the same licensed circle. This sharing of resources would make Continued Demand for Cost Reduction (CAPEX) and Operating Expenditure (OPEX) savings for operators. ICR helps in faster roll out and acquiring of sites and the coverage at almost no new infrastructure added at the radio interface level.

II. USER REGISTRATION AND MOBILITY

3G Intra Circle Roaming agreement between the two operators is based on the following assumptions considering operator A (Op-A) is the donor who provides the infrastructure for sharing to operator B (Op-B) who is the seeker.

- Op-A has both 2G and 3G network and Op-B has only 2nd Generation (2G) network.
- Op-A has same PLMN ID for both 2G and 3G network.
- LAC/RAC is different for each 2G/3G network. Operator having both 2G-3G network will also have different LAC/RAC for 2G-3G in the same ICR area.
- No separate International Mobile Subscriber Identity (IMSI) for Op-A and Op-B for 3G subscribers.

3G ICR implementation requires changes and new connections to be made at the core interfaces of both the

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partners. Initially a mapping tool is utilized to determine which Node-B sites are required for the seeker operator to be donated. Normally a certain range of 400m to 1 km circle range sites which do not have seeker operator 3G coverage is chosen for implementation. The following procedures provide an insight of how these changes are made at the radio interface.

A. Camping in partner's 3G network

Radio Resource Connection defines 2 types of modes, the idle mode and the connected mode. Idle mode requires the cell to broadcast its parameters to Node-B and the connected mode establishes the call or data connection to take place. In idle mode the User Equipment (UE) first scans the frequencies in the area and then searches for a suitable cell of the its home PLMN if available or else chooses the previously connected PLMN and chooses the registered operator to provide services and modifies to its control channel. This method of selecting a cell is being referred as "camping on the cell". The User Equipment may then broadcast its present location by a Non-Access Stratum registration, provided by the success of a location registration. The PLMN which is chosen becomes the registered PLMN [8]. Fig. 1 shows initial roaming procedures flow diagram.

For normal roaming conditions, the following scenario occurs at the core interfaces,

- UE initiates Location update procedures with Mobile Services Switching Centre (MSC)/Visitor Location Register (VLR) and Universal Mobile Telephone System (UMTS) authentication is performed.
- Home Location Register (HLR) updates the roaming subscriber new location to the new MSC and VLR database via a Roaming Support Gateway (R-SGW).
- Mobile Application Part (MAP) messages are sent from home subscriber HLR to the MSC and vice versa for subsidiary applications such as usage of internet, SMS, etc.
- MAP cancel location message is sent to acknowledge about changing to new era which may be sent to home subscriber HLR.

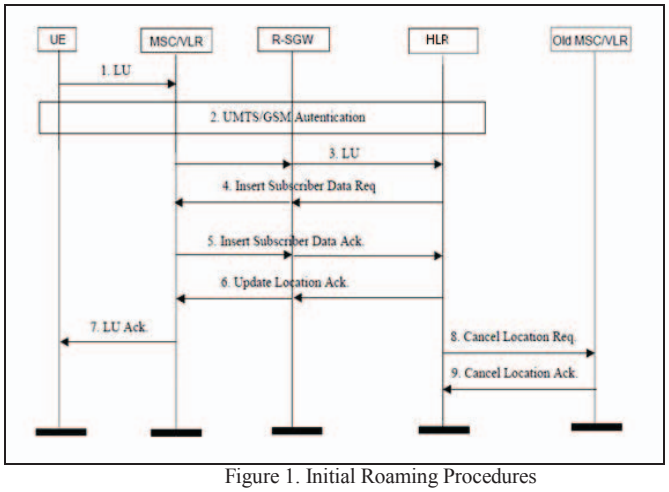

Figure 1. Initial Roaming Procedures

When a PLMN has been selected by NAS (non-access stratum) which maintains the list of PLMN with the forbidden lists, the User Equipment may attempt to find a suitable cell to camp. The UE selects the cell if it is found and move this event to NAS in order to perform the NAS registration procedures. Any cell selection state will be entered by the UE if there are no suitable cells. Cell Reselection takes place if the Received Signal Code Power (RSCP) level goes down and the UE cannot latch on to the VPLMN. The neighboring cells supporting the host should be able to monitor the UE for camping again [9]. Fig. 2 shows the camping of mobile in partner 3G networks.

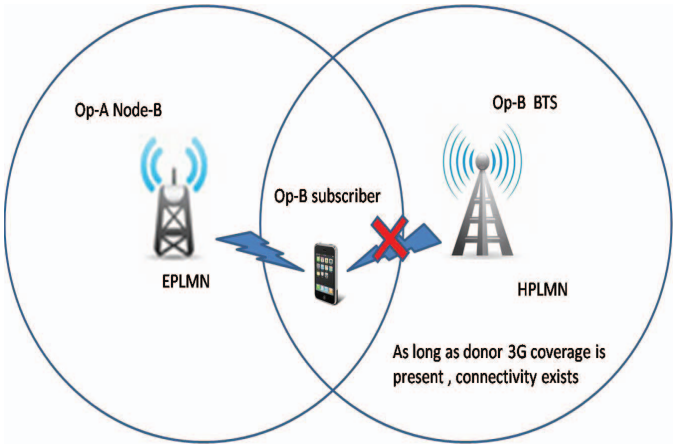

Figure 2. Camping of mobile in partner 3G networks

B. Mobility Restriction

Location of a Mobile Station in the PLMN is uniquely identified by a specified number called the Location area Identity (LAI). MCC/MNC is the mobile country/network operator code and the LAC is the Location area code of 16 bits info. LAI = MCC+MNC+LAC. Using this information we could make a mobile to restrict its access in the donor operator area so as to get seamless 3G coverage. Mobility restriction of roamers is made possible by 2 ways,

- Location Area Code (LAC) based Restriction
- HLR based Access Restriction

Location area/Routing area code could be created by donor 3G operator for its coverage area. IMSI range of seeker MS could be included in 3G LAC/RAC but not in the 2G LAC/RAC thus preventing the MS to latch into the donor 2G networks. Rejection cause sent to MS for LU for restricted LAC is also important and should be set to 'Roaming not allowed in this location area (LA)'. If the rejection cause is set to 'PLMN not allowed', the list of "Forbidden PLMNs" by the VPLMN identity stored in a data field in the SIM (Subscribe Identity Module)/USIM (User Service Identity Module).

C. Pullback Mechanism

In the ICR regions where both seeker and donor have 3G networks, the seeker MS once latched to donor 3G network should be pullback to its home (seeker) network if the home network signal strength is higher than that of the ICR partner (donor) network. This could be possible by a pullback

mechanism that needs a software change at the core level. This could be described in 2 ways,

- Network based Solution
- SIM based Solution

In the Network based solution, a Smart Roam platform is implemented which makes the roamers to latch to home network. Once when the Location update is received from the MS, HLR triggers the platform and sends the Location info file (LOCI) clear command which would get active by next time the mobile searches for PLMN. This clear command would make the UE scan for home network if possible and latches on it. A Location Update is made periodically for every 30 min.

The SIM based solution requires an application to be created in the SIM module. The application in the SIM would continuously scan for the home PLMN at regular intervals of 6 min, 12 min, 18 min or 30 min depending on the operator specifications. After the interval period the SIM has to scan for its home network if the home network signal strength is greater than that of the ICR partner.

III. CORE LEVEL CHANGES

At the core interface the main architecture change in network connectivity between the ICR partners lies in the allocation of a dedicated trunk group (TG) for its ICR traffic. ICR traffic monitoring is done at the home network which would generate Call Detail Records (CDR) for its subscribers. This would reduce complexity for donor operator to do generate CDR for in-roaming subscribers. The traffic flow between operators is shown in Fig. 3.

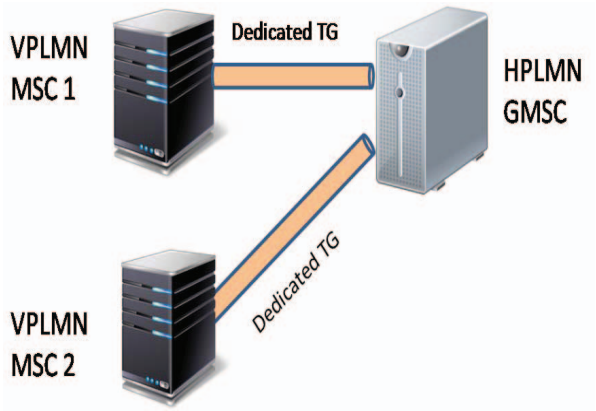

Figure 3. Traffic flow between operators

Dedicated Trunk groups need to be established between Visited Network MSCs and Home Network GMSCs for the in-roamers to the VPLMN. An in-roamer is a type of roamer with no subscription and direct billing to the VPLMN. All the calls originated by the in-roamer need to be routed to home network via the dedicated trunk group lines. The in-roamer is considered as the Mobile Subscriber Roaming Number (MSRN) which is a temporary mobile number assigned to a mobile station which roams into another numbering area.

The calls originated by the in-roamer will be handed over the dedicated TG to home network within the same circle. Dedicated TG is very critical as it is present in the Call Detail Record (CDR) file and used for revenue reconciliation by Operators. The following procedures present a detailed scenario of how a call, SMS and data initiation process takes place while the UE is roaming under ICR considerations.

A. Voice Call Procedures

The architecture of a MO call and MT are shown in Fig. 4. and Fig. 5 respectively. The following conditions provide how a circuit switching connection is made for two cases:

- MO (Mobile Originating) call
- MT (Mobile Terminating) call

For a call connection of MO case,

- For a Mobile Station Roaming Number (MSRN) subscriber making a call under operator A, first the initial signaling connectivity is established via Radio Frequency (RF) parameters.
- At the Radio network Controller (RNC)/Base Station Subsystem (BSS) the initiation of the call and the resources to be allotted are decided and is sent as a request to the core element.
- It then involves SS7 signaling protocol messages which decide the routing conditions.
- Then the validity of the subscriber is checked by VLR which then gives a Send Info for Outgoing Call (SIFOC) message to MSC. Before that the VLR should consider the MS as in-roamer and update its database by LAC updating procedures.
- The MSC then routes the call to the Global MSC (GMSC) of the home operator via the dedicated lines from where the call then gets routed to the Synchronous Transport Module (STM) lines for further routing to reach the destination [10].

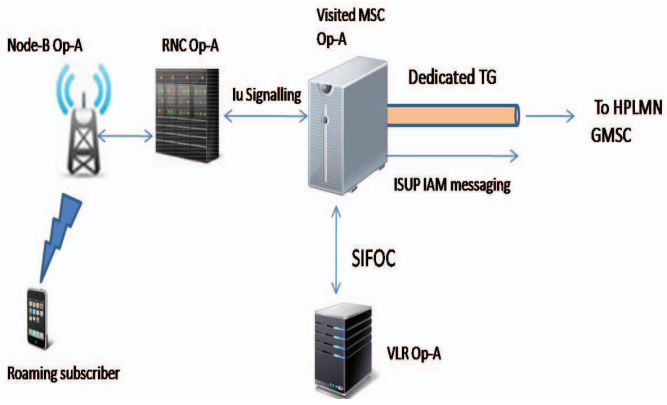

Figure 4. Architecture of a MO call

For a call connection of MT case,

- For a subscriber receiving the call under operator B, the initial case would be the continuous signaling connectivity with operator by broadcast parameters.

- When the GMSC B receives the ISUP IAM, it requests the routing information from HLR B. If the subscriber is not in home register, it then validates for the subscriber in VLR B under roaming conditions.
- After the validation of the MSRN, an acknowledgement is sent from HLR B to GMSC B where the ISUP IAM is transferred to MSC. The MSC makes arrangements for the call to establish via the dedicated TG.
- An acknowledgement message Send Info for Incoming Call (SIFIC) is initiated to VMSC B describing the destination and the route to RNC.

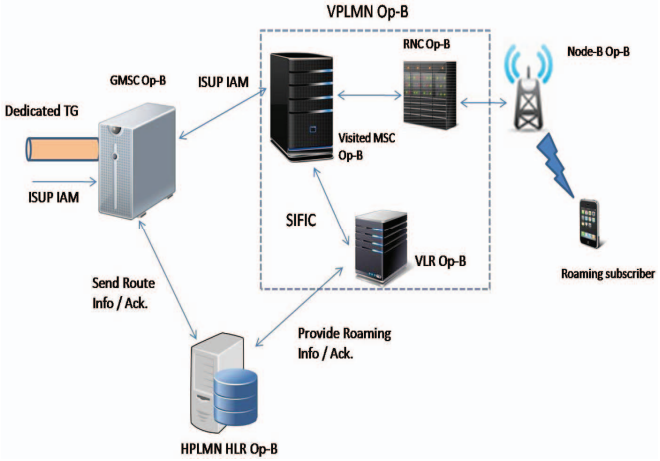

Figure 5. Architecture of a MT call

B. *Network Connectivity*

For ICR Connectivity to be established between the operators, the necessary signaling is to be made at the core level elements,

- ICR location areas are provided separate LAC.
- STP and GMSC signaling are to be made between the operators.
- Firewall and Border gateway configurations are made.
- Various other services such as Call Back Ring tone (CBRT), Missed Call Alert (MCA) and other IN services are configured.
- Both operators need to exchange the signaling information, which includes the SMSC GT, IN GT, HLR GT, MSC addresses for seamless flow of MAP signaling messages between core elements.
- Roaming number range needs to be configured in Home network for delivery of terminating call.

The diagram of the core level network connectivity is shown in Fig. 6.

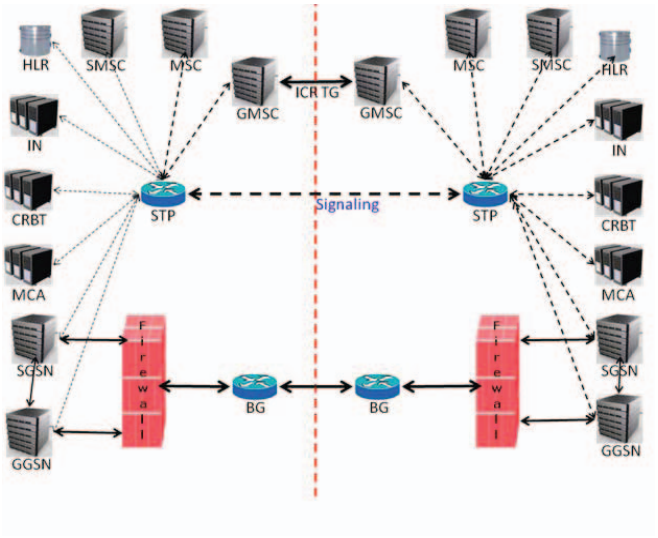

Figure 6. Core level Network Connectivity

A Point of Interface (POI) provided for connectivity to PSDN, Internet and to other operators. The KPI values should be satisfactory to both the operators. Prepaid Charging for voice and SMS requires CAMEL (Customized Applications for Mobile Enhanced Logic) protocols [11]. CAMEL provides a platform for intelligent networks that allow an operator to define services over and above standard UMTS services. The call flow in ICR is shown in Fig. 7.

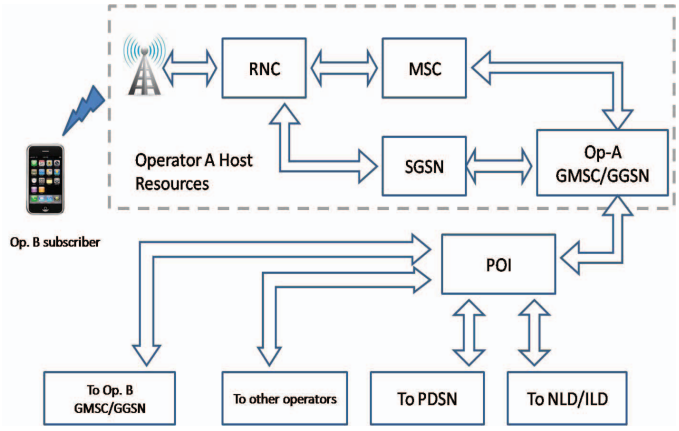

Figure 7. Call Flow in ICR

C. *SMS Connectivity*

The Short Messaging Service provides transfer of messages between a user equipment may be GSM or UMTS standard and a SME by a Service Centre. The Service center acts as an internetworking and a relaying function of the message transfer between the UE and the SME [12]. The flow of SMS connectivity architecture is shown in Fig. 8. SMS services are of 2 types:

- SMS MT (Mobile Terminated)
- SMS MO (Mobile Originated)

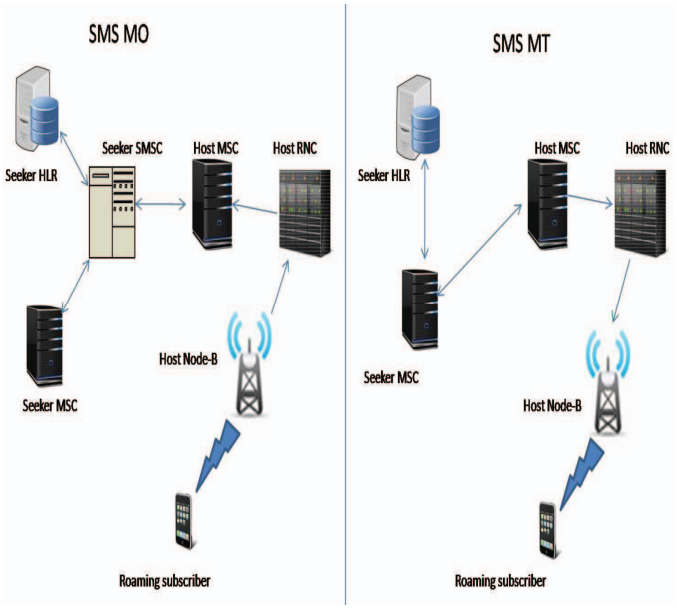

Figure 8. SMS Connectivity Architecture

For ICR Considerations the SMS connectivity traffic is made through dedicated TG line and supports A2P (application to person) and P2P (person to person) protocols. In the case of MO, SMS originating from roamer utilizes Node-B, RNC of host operator and reaches SMSC server where it is routed to seeker operator MSC via TG link. Seeker operator then checks validity of destination and is routed via its own links. In this case of SMS MT, the SMS is routed to host HLR under which the roaming subscriber is camped. This requires validity of the seeker MS to point its presence to Seeker HLR that it is roaming in the partner network.

D. Data Connectivity

The Packet Data Protocol context activation for General Packet Radio Service (GPRS) procedure may be initiated either by the user or the Gateway GPRS Support Node (GGSN).

1) Initiated by MS

Whenever a User Equipment wish to access internet by a PDP context, the MS forwards a PDP ACTIVATION REQUEST message to the Serving GPRS Support Node with some parameters such as the Quality of Service, NSAPI (Network Service Access Point Identifier), subscriber PDP activation address and Access Point Name (APN) configurations. The NSAPI is broadcasted by the MS around the area where it is not temporarily used for other MS. A PDP address can be provided only if the MS already has a static IP address.

Certain security functions are to be utilized for authenticating the MS. The SGSN can now derive the Gateway GSN address from the Access Point Name identifier for forwarding the required request to the Gateway GPRS Support Node. The SGSN creates a downlink GPRS Transfer Protocol tunnel for routing the data packets from the GGSN to Support GSN. Fig. 9 and Fig. 10 show a PDP context activation initiated by MS and GGSN respectively.

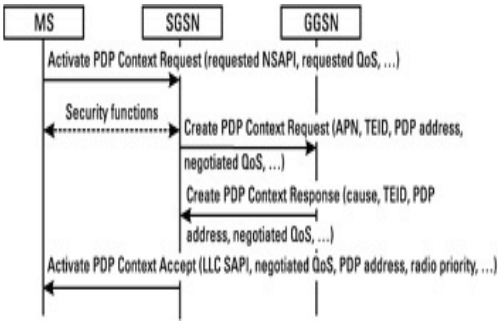

Figure 9. MS initiates the PDP context activation

The GGSN now provides creation of a newer entry in packets between the SGSN and the packet-switching network.

2) Initiated by GGSN

Whenever the operating network receives an IP packet from a different packet support network, the GGSN validates if a PDP context is currently established with that specified PDP address. If no context activation is previously done, then the GGSN sends a PDU NOTIFICATION REQUEST to the Support GSN for initiating the PDP context activation. The GGSN has to retrieve the IP packet address of the required Support GSN address by interrogation of the Home Location Register by the International Mobile Subscriber Identity (IMSI) of the User Equipment. The SGSN then forwards to the UE an activation request of the pointed PDP context. Once when the PDP context activation is done, the data packets are to be forwarded from the Gateway GSN to the UE.

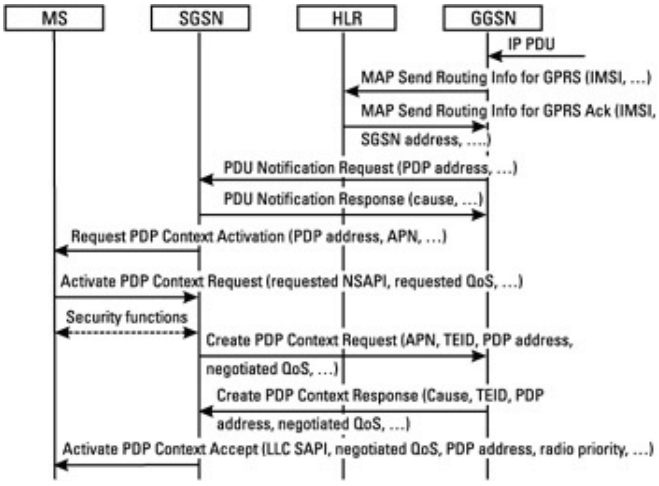

Figure 10. PDP context activation initiated by GSSN

The basic PDP activation in roaming is same as in normal conditions except that in ICR, the network could be effective if we provide a direct connectivity via the Border Gateway routers rather than via the GPRS Roaming Gateway [13].

Fig. 11 shows a PDP context activation in ICR .Under ICR scenarios, the Context activation is done under certain considerations as,

- The host operator Domain Name System (DNS) server will respond to its Serving GPRS Support Node (SGSN) about the PDP request.

- This request will be acknowledged by the seeker GGSN and IP tunnel is created between the host SGSN and seeker GGSN.
- Data is monitored by seeker GGSN.
- Charging is done via Diameter Interface in Intelligent Network (IN) protocol.
- Authentication centre (AuC) at the core network provides algorithms and generates keys.

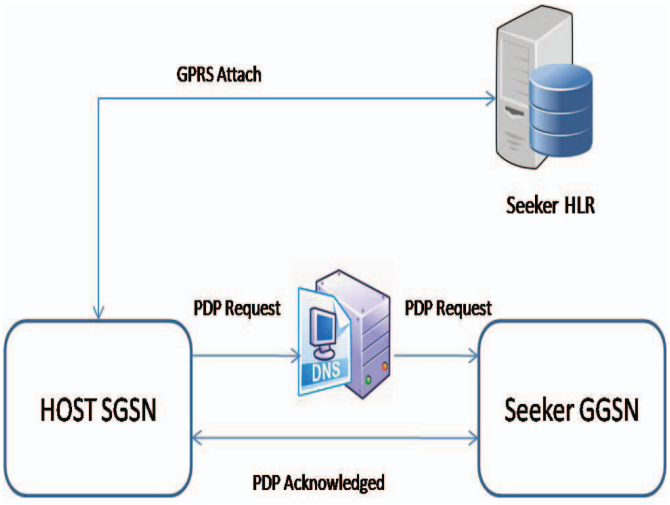

Figure 11. PDP context activation in ICR

IV. ICR Site Identification

Site Identification procedure is done at the network planning level where sites required to be considered for implementation of ICR. A sample database considering the sites of seeker and donor sites of a circle is loaded in the mapping tool. The mapping tool is to be utilized in such a manner so as to identify which sites of donor operator come under the seeker 3G. These sites are removed and the sites which have a larger separation from the donor operator could be considered for implementing this agreement.

A sample site identification process requires graphical analysis and mapping tool. Normally the 3G sites which overlap with partner for a specified radius are not taken for consideration. The seeker operator sites which are far from access from its operator neighbors and near to donor sites are selectively chosen and considered for implementation. The following scenario provides 2 cases of why a site is chosen for ICR consideration. Fig. 12 and Fig. 13 show a sample town which is proposed for ICR and a sample town which is not proposed for ICR respectively.

A. Sample town proposed for ICR – Case 1

The below mentioned scenario visually provides information that the most of the sites of both the partner operators are well above 2 km with most of the sites not near to partner sites and if the sites are agreed for ICR, the subscribers of both operators would be benefitted with 3G coverage throughout the area.

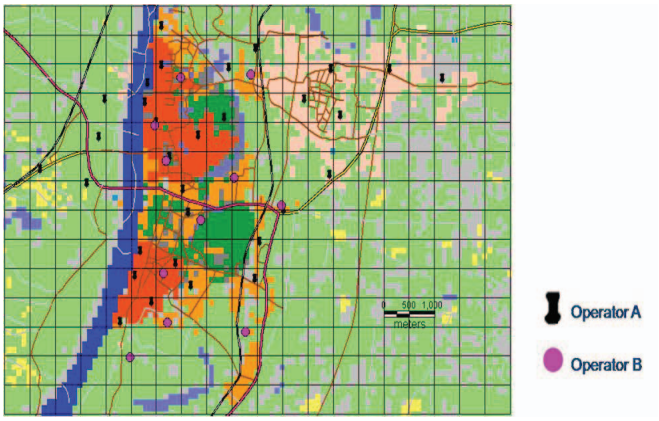

Figure 12. Sample town proposed for ICR

B. Sample town which is not proposed for ICR – Case 2

The above scenario obtained in the mapping tool suggests that the both of the partner sites are within the range of less than 1 km which suggests that if they are implemented for ICR, the subscribers wouldn't be benefitted since the home network will be present always for both the subscribers. Moreover analysis shows that the some of the sites are do implemented on a same tower indicating passive infrastructure sharing is done which would not provide any improved coverage and implementation would be of no use.

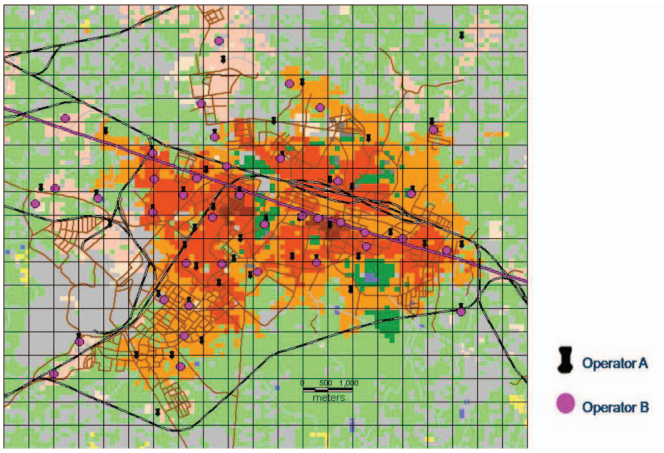

Figure 13. Sample town which is not proposed for ICR

ICR testing requires field observations with the Radio interface connectivity issues. Once when the TG, border gateway and firewall connections are made for both the operators, testing is done with a sample U-SIM of seeker operator subjected to the drive test made under the implemented circle.

V. Conclusions

The current telecom industry faces a challenge of implementing newer technologies to the people at a faster rate than to go out for roll out for new sites which would eventually takes more time to implement. With the obtaining of licensed spectrum, operators are in a need to provide services that could be possible without the need of new infrastructure to obtain from vendors. To keep up with the global market and to

provide technology services for the benefit of the nation, the government approved for Intra Circle Roaming which thereby proves that the operator expenditure could be effectively reduced and this could make developing nations to achieve innovative technology implementations at a faster rate.

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