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Technical **Brief**

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Inter-Operator Mobility with CBRS

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Executive Summary

This technical brief provides the test results for two 3GPP-based network roaming models—Home Routed (HR) and Local Break Out (LBO)—that could help multiple service operators (MSOs) deliver inter-operator mobility between MSO-owned Citizens Broadband Radio Service (CBRS) networks and licensed LTE networks owned by mobile network operators (MNOs). Understanding the benefits and tradeoffs for each model can better position MSOs to implement an apt solution based on MSO infrastructure ownership and mobile virtual network operator (MVNO) agreements.

MSOs may be motivated to provide mobile services utilizing the new 3.5 GHz spectrum introduced with CBRS. However, because CBRS operates low-power small cells to provide localized coverage in high-traffic environments, an MSO may rely on MVNO agreements to provide mobile service outside the CBRS coverage area. In this scenario, an MSO will be motivated to

- deliver seamless transition,
- minimize transition time between the home CBRS network and the visitor MVNO network, and
- maximize device attachment to the home CBRS network.

Tests on implementations of HR and LBO roaming models were conducted in the mobility lab. LTE networks using Band 41 (2.5 GHz) and Band 43 (3.5 GHz), representing an MNO network and an MSO's CBRS network, respectively, were used to test inter-frequency and inter-PLMN (Public Land Mobile Network) transition in both the connected (i.e., active data session) and idle modes.

The HR implementation is ideal for MSOs that have MVNO agreements with MNOs that allow sharing of roaming interfaces (i.e., S6a, S8, and S10) and provide control over mobility configuration. HR offers seamless data session continuity with inter-frequency, inter-PLMN S1 handovers in connected mode and cell reselection in idle mode, with more control of a subscriber's traffic.

The LBO implementation is ideal for MSOs that do not have an MVNO agreements with MNOs that allow sharing of roaming interfaces or provide control over mobility configuration. Therefore, LBO will not offer seamless data session continuity in connected mode or cell reselection in idle mode while moving from an MNO network to an MSO network.

Please refer to the "Test Observations and Results" section for a high-level summary of the results for both roaming models with regard to shared roaming interfaces, the need for mobility configuration, mobility triggers used, network transit duration, etc.

Alternate solutions to enhance inter-operator mobility with minimal reliance on MNO network interfaces and mobility triggers were also investigated. These solutions include using external servers for device mobility control and enhancing dual-SIM implementation to make devices smart enough to switch between multiple operators.

Introduction

The emergence of the newly allocated Citizen Broadband Radio Service (CBRS) shared spectrum has unlocked opportunities for new entrants, including traditional multiple service operators (MSOs), to provide mobile service. One common use case for new entrants is to deploy CBRS networks in high-traffic areas served by low-power small cells. This use case would enable delivery of mobile service in localized areas in a market to meet business-case objectives. However, if the use case includes providing market-wide coverage, a CBRS operator may need to rely on macro-cell network coverage to provide mobile service outside CBRS network coverage. Mobile virtual network operator (MVNO)[1] agreements with mobile network operators (MNOs) are a common solution to support this strategy.

The biggest challenges to making this MVNO use case successful for an MSO CBRS operator are providing seamless or timely transition between the two networks and ensuring the subscriber stays connected to the CBRS network while in an overlapping MNO-owned LTE network coverage area (i.e., LTE offload).

For inter-operator roaming, mobile operators use one of the two 3GPP roaming standards, namely Home Routing (HR) and Local Break Out (LBO), to support transition between a home network and roaming partner visitor networks. The international or domestic roaming agreements between operators of the home and visitor networks require the two networks to share roaming interfaces, as dictated by the 3GPP defined roaming models.

Because mobile operators are motivated to keep their subscribers on their networks as long as possible to minimize LTE offload, they have little incentive to provide open access and connection to their MVNO partners. Thus, CBRS operators and host MVNO operators may have different and opposing motivations.

This technical brief investigates the tradeoffs between levels of access and the network interconnection required between CBRS and licensed LTE networks to (1) deliver seamless transition, (2) minimize transition time between the home CBRS network and the visitor LTE network, and (3) maximize device attachment to the home CBRS network. The 3GPP Home Routing and Local Break Out roaming models were used as a baseline; tests were conducted in the CableLabs Mobility Lab.

The following aspects were evaluated in the lab environment using HR and LBO configurations:

- inter-operator mobility using network-based triggers for connected and idle modes,
- sharing of roaming interfaces,
- Public Land Mobile Network (PLMN) configurations, and
- higher priority network selection timer.

The following alternative solutions to network-based transition were discussed:

- device transition controlled with an external server and
- enhancing dual SIM functionality.

This technical brief will provide key findings that may assist MSOs in evaluating the implementation of the two roaming models in this CBRS use case.

[1] An MVNO is a mobile operator that does not own a mobile network or licensed spectrum but rather makes an agreement with a mobile operator to obtain access to its network services at a wholesale rate in order to resell those services at a different rate.

Background

This section provides an overview of the two 3GPP-defined network implementations for roaming: Home Routed (HR) and Local Break Out (LBO).

Home Routed (HR) with S10

In the HR model, the user data traffic is serviced by the home network, giving the home network operator control over the subscriber's traffic. The HR model is preferred when the visitor network provider is not reliable enough to service the home network subscriber's data. Figure 1 shows the network architecture for the HR model, with two networks sharing the S6a, S8, and S10 interfaces.

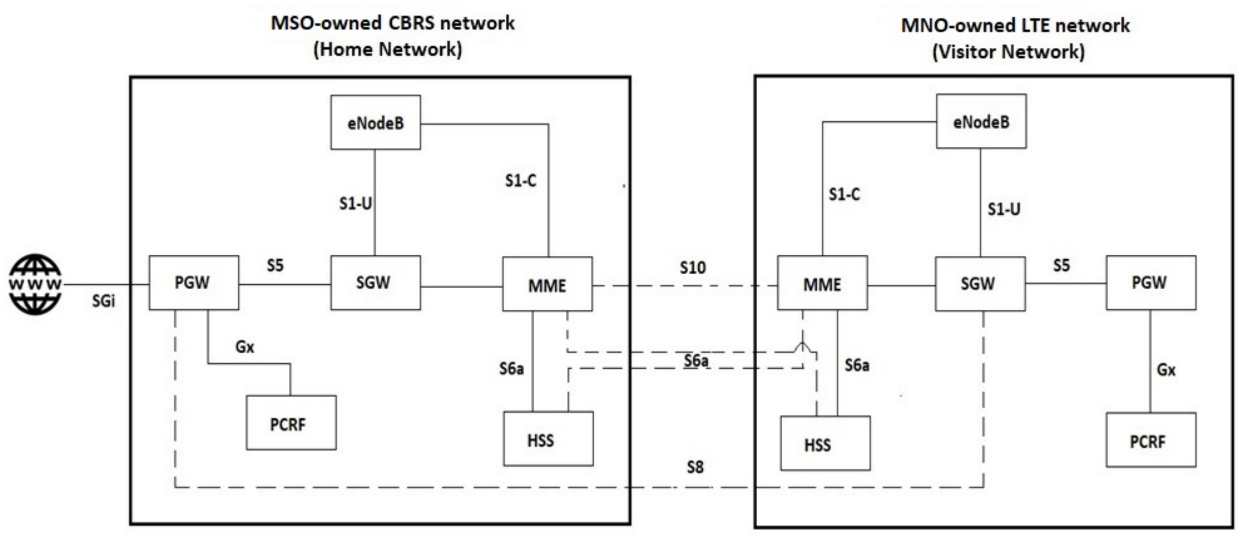

Figure 1: Home Routed (HR) Network Architecture

For HR implementation with S10, the two operators need to share the following roaming interfaces:

- S6a—an interface between the Mobility Management Entity (MME) and the Home Subscriber Server (HSS) that enables the transfer of subscriptions for authenticating and authorizing user access to the network.
- S8—an interface between the Serving Gateway (SGW) of the visitor network and the Packet Gateway (PGW) of the home network, acting as an inter-PLMN reference point to transfer user traffic back to the home network. S8 allows the home network to control a subscriber's traffic even when the subscriber is roaming on the visitor network.
- S10—an interface between two MMEs used for bearer modification with MME relocation and MME-to-MME information transfer. S10 enables seamless data session transfer in connected mode.

In addition to sharing roaming interfaces, HR implementation requires each network to be configured with mobility parameters that utilize connected- and idle-mode triggers.

Local Break Out (LBO)

In the LBO model, the user data traffic is serviced by the visitor network when the home network operator's subscriber roams on the visited network. The LBO model requires less bandwidth and latency because the user data traffic is routed through the PGW of the visitor network. This model is preferred when there is a trusted relationship between the two operators. In LBO, only the S6a interface needs to be shared between the two operators. Additionally, it does not require connected-mode mobility triggers to be configured on the visitor network.

Figure 2 shows the network architecture for the LBO model, with two networks sharing the S6a interface.

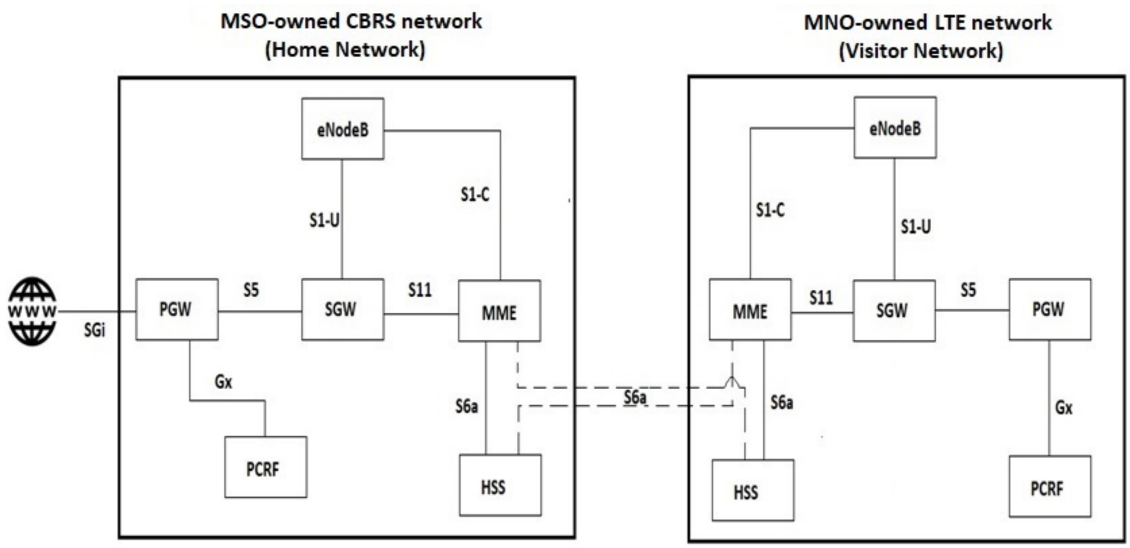

Figure 2: Local Break Out (LBO) Network Architecture

Test Overview

This section provides an overview of the test setup and the connected- and idle-mode mobility triggers configured on both home and visitor networks, subscriber identity module (SIM) configurations with regards to PLMN, and MSO CBRS use cases used to test the two 3GPP-based roaming implementations.

Test Setup

The lab setup consisted of two instances of virtualized evolved packet cores (vEPCs) and two radio access network (RAN) eNodeBs. Each eNodeB/vEPC pair depicted a different kind of operator network: the pair operating in Band 43 (3.5 GHz) represented an MSO-owned CBRS network, and the pair operating in Band 41 (2.5 GHz) represented an MNO-owned LTE network. The handover and cell reselection procedures were tested 10 times to validate the repeatability of the test results; the procedures used the 3GPP-defined messaging and time required for transition between operator networks. Both connected-mode and idle-mode triggers used Reference Signal Received Power (RSRP) as the basis for thresholds.

Connected-Mode Triggers

The connected-mode handover is performed when the device has an active data or voice session. There are five triggers for intra-LTE connected-mode handovers.

- Event A1 - Triggered when serving cell signal becomes better than threshold
- Event A2 - Triggered when serving cell signal becomes worse than threshold
- Event A3 - Triggered when neighboring cell signal becomes better than serving cell signal by an offset
- Event A4 - Triggered when neighboring cell signal becomes better than threshold
- Event A5 - Triggered when serving cell signal becomes worse than threshold and neighboring cell signal becomes better than threshold

The inter-frequency, inter-PLMN S1 handover can be triggered using Event A2 and A3 or using Event A2 and A5. We used Event A2 and A5 to test connected-mode handovers because the A5 trigger validates the RSRPs of the serving and neighboring cells relative to an absolute threshold value. The A3 trigger only validates the RSRPs of the serving and neighboring cells relative to each other. Using Event A5, reduces the risk for the device to “ping-pong” (i.e., move back and forth) between the serving and neighboring cells.

Idle-Mode Triggers

The idle-mode cell reselection is performed when the device has no active data or voice session. There are two triggers for idle-mode cell reselection.

- The following trigger was used when moving from the lower priority LTE network to the higher priority CBRS network.

  S (non-serving cell, x) > Thresh (x, high)

  where
  Thresh (x, high) is the absolute threshold used for higher priority cells broadcasted in SIB 5
  S (non-serving cell, x) is the recorded RSRP value of non-serving cell (neighboring cell)

- The following trigger was used when moving from the higher priority CBRS network to the lower priority LTE network.

  S (serving cell, x) < Thresh (serving, low)

  S (non-serving cell, x) > Thresh (x, low)

  where
  Thresh (serving, low) is the absolute threshold applied to the serving cell used with lower priority cells broadcasted in SIB 3
  Thresh (x, low) is the absolute threshold applied to the neighboring cell used with lower priority cells broadcasted in SIB 5
  S (serving cell, x) is the recorded RSRP value of the serving cell

PLMN Configurations

The network implementations tested for connected and idle mobility were validated using two types of SIM configurations:

- In the Home PLMN (HPLMN)/Visitor PLMN (VPLMN) configuration, the PLMN broadcast by the home network provider has higher priority over the PLMN broadcasted by the visitor network provider by default. The device displays the “LTE” symbol when serviced by the home network and the “R” symbol when serviced by the visitor network.
- In the Equivalent Home PLMN (EHPLMN) configuration, the PLMNs from both networks are considered as HPLMNs by the device. The device does not display the roaming symbol “R” on the device screen when attached to either network. EHPLMN allows operators to provision and assign priorities to multiple HPLMNs.

MSO Use Cases with CBRS Deployment

The two 3GPP-defined network implementations for roaming, Home Routed (HR) and Local Break Out (LBO), can be applied to different MSO use cases, as shown in Figure 3. The use cases include scenarios for moving devices dynamically and in real time between the MSO-owned CBRS network and the MNO-owned licensed LTE network:

- Device transitions to an MNO LTE network when outside the coverage area of a CBRS network—in idle mode for both HR and LBO and with seamless data session transfer in connected mode for HR
- Device transitions from an MNO LTE network to a CBRS network as soon as the device enters the CBRS coverage area—in idle mode for both HR and LBO and with seamless data session transfer in connected mode for HR

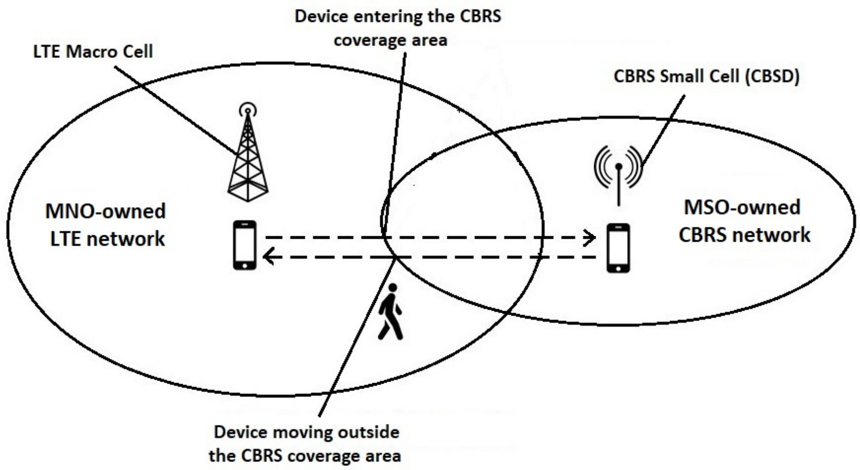

Figure 3: Inter-Operator Mobility MSO Use Case with CBRS

Test Observations and Results

This section describes the observation and results for Home Routed (HR) and Local Break Out (LBO) roaming implementations when applied to MSO use cases in both connected- and idle-mode scenarios. See Table 1 for a high-level summary of the results. This section also includes the following:

- network-based triggers used for testing,
- observations on service disruption, and
- results of the time taken by the end device to transition between the networks.

Table 1: Summary of Results

Comparison Metric	Network Implementations	
	Home Routed (HR)	**Local Break Out (LBO)**
Shared interfaces	Three: S6a, S8, and S10	One: S6a
Mobility configuration needed on MNO network	Yes	No
Mobility triggers	Connected Mode: S1 handover Idle Mode: Cell reselection	Connected Mode: Blind redirection (MSO to MNO) and radio link failure with reattach (MNO to MSO) Idle Mode: Higher Priority PLMN (HPPLMN) Search Period
Network transition time	Connected Mode: 500–600ms Idle Mode: 100–200ms	Connected Mode: 500–700ms (MSO to MNO); 800–900ms (MNO to MSO) Idle Mode: 100–200ms (MSO to MNO); 6min (MNO to MSO)
Connected-mode mobility	Seamless handover via S10	Service disruption without S10
Key benefit	Seamless connected-mode mobility	Less dependency on MNO
Tradeoff	More dependency on MNO	Non-seamless connected-mode mobility

Home Routed (HR)

For the HR implementation with S10, the connected-mode mobility was performed with inter-frequency, inter-PLMN S1 handovers using Event A2 and Event A5 triggers, and the idle-mode mobility was performed with cell reselection using idle-mode mobility parameters. The connected-mode mobility was tested using active data sessions. Voice sessions were not tested; however, it is expected that voice sessions should behave similarly to data sessions during seamless transitions between the networks.

Connected Mode

The trigger values A5 RSRP 1 and A5 RSRP 2 were chosen to successfully trigger the handover in a controlled lab environment. The thresholds to trigger the handover can be optimized for real-world deployments. From the MSO perspective, connected-mode handover triggers such as A5 should be set aggressively for moving from MNO to MSO networks; triggers for moving from MSO to MNO networks should be less aggressive. The trigger values decide only when the handover will be initiated and do not change the duration needed for the actual handover process.

Table 2 provides the connected-mode mobility trigger values used for lab testing as well as illustrative values that MSOs and MNOs may use to keep the device on their network as long as possible in overlapped coverage.

Table 2: HR Connected-Mode Mobility Trigger Values

	HR Connected-Mode Mobility Triggers					
	MSO network (higher priority)			MNO network (lower priority)		
	A2 RSRP	**A5 RSRP 1**	**A5 RSRP 2**	**A2 RSRP**	**A5 RSRP 1**	**A5 RSRP 2**
Values that can be used by MSOs in field	-60dbm	-120dbm	-110dbm	-60dbm	-85dbm	-115dbm
Values used for testing	-65dbm	-80dbm	-80dbm	-65dbm	-80dbm	-80dbm

With HR implementation, connected-mode handovers took approximately 500–600ms to transit between the networks irrespective of whether the SIM used EHPLMN or HPLMN/VPLMN configuration. In addition, there were no service disruptions during connected-mode handovers.

The inter-frequency, inter-PLMN S1 handover in connected mode between the two networks validates the MSO use case: there was seamless data session transfer when moving to the MNO network outside the coverage area of the MSO CBRS network and when moving back to the MSO CBRS network.

Idle Mode

The trigger values ThreshXHigh, ThreshXLow, and ThreshXServing were chosen to successfully trigger the cell reselection in a controlled lab environment. From the MSO perspective, the idle mode cell reselection triggers such as ThreshXHigh should be set aggressively for moving from MNO to MSO networks; triggers such as ThreshServingLow and ThreshxLow should be set less aggressively for moving from MSO to MNO networks. The trigger values decide only when the cell reselection will be initiated and do not change the duration needed for the actual cell reselection process.

Table 3 indicates the idle-mode mobility trigger values used for lab testing as well as values that MSOs can use to keep devices connected to a CBRS network longer and to have devices fall back to an MNO LTE network only when radio conditions are poor.

Table 3: HR Idle-Mode Mobility Trigger Values

	HR Idle-Mode Mobility Triggers		
	MSO network (Higher Priority)		MNO network (Lower Priority)
	ThreshXLow	**ThreshServingLow**	**ThreshXHigh**
Values that can be used by MSOs in field	-120dbm	-110dbm	-120dbm
Values used for testing	-110dbm	-80dbm	-112dbm

For idle-mode cell reselection, the device behavior was not consistent with a multiple-PLMN setup; however, it was consistent with a single PLMN configuration on both networks. The idle-mode reselection took approximately 200–250ms to transit between the networks after the expiry of the inactivity timer, which was set to 10s (i.e., the default value used in most commercial networks).

Idle-mode cell reselection between the two networks validates the MSO use case: the device transitioned to the MNO network when outside the MSO CBRS network coverage area and transitioned to the MSO network when back inside the MSO CBRS network coverage area.

Benefits and Tradeoffs

The HR implementation is ideal for MSOs that have MVNO agreements with MNOs that allow sharing of roaming interfaces and provide control over mobility configuration. HR offers seamless data session continuity with inter-frequency, inter-PLMN S1 handovers in connected mode and cell reselection in idle mode with more control of the subscriber's traffic.

The key benefits of an HR implementation include

- seamless mobility in connected mode with bearer context transfer via S10 and user traffic routing to the home network via S8 and
- an anchor-point back to the MSO network via S8 for easier policy enforcement and charging and billing functionality.

The tradeoffs of an HR implementation include

- high dependency on an MNO network to share roaming interfaces and configure mobility parameters and
- increased latency with user data traffic being routed back to the home network.

We also tested an HR implementation without an S10 interface, that is, with only S6a and S8 interfaces. The mobility behavior of an HR implementation without S10 is similar to LBO. The advantage of implementing HR with only an S8 interface is that the home network can control subscriber traffic when the subscriber is roaming. The disadvantage of implementing HR without S10 is that seamless handovers cannot be performed in connected mode for data and voice sessions.

Local Break Out (LBO)

With the LBO implementation, the connected-mode mobility was performed with blind redirection while moving from the MSO network to the MNO network. Blind redirection initiates a device connection release specifying the target frequency to which the device should attach after an Event A2 is triggered. While moving from the MNO network to the MSO network, the device is released with a radio link failure (RLF) and attempts to reattach to the MSO network because there is no bearer context transfer via S10.

The idle-mode mobility performed for moving from the MSO network to the MNO network was similar to that used in HR. When moving from the MNO network to the MSO network, the Higher Priority PLMN (HPPLMN) search period timer was used.

Connected Mode

The A2 threshold value was chosen for testing to successfully trigger blind redirection in a controlled lab environment. From the MSO perspective, the connected-mode blind redirection triggers such as the A2 threshold should be set less aggressively when moving from MSO to MNO networks. The trigger value decides only when the blind redirection will be initiated and does not change the duration needed for the actual blind redirection process.

Table 4 indicates the connected-mode mobility trigger values used for lab testing as well as values that MSOs can use to keep devices connected to a CBRS network longer and to have devices fall back to an MNO LTE network only when the radio conditions are poor.

Table 4: LBO Connected-Mode Mobility Trigger Values

	MSO network (higher priority) Blind A2 RSRP
Values that can be used by MSOs in field	-120dbm
Values used for testing	-100dbm

With LBO implementation, blind redirection took approximately 500–700ms for the device to transition from the MSO network to the MNO network, irrespective of whether the SIM used EHPLMN or HPLMN/VPLMN configuration. While moving from the MNO network to the MSO network, the device continued to stay on the MNO network until it was outside the MNO network coverage area, at which point it reattached to the MSO network. The reattach after the radio link failure took approximately 700–800ms. Because the device context was released, and because the device had to perform a fresh attach while moving between the two networks, there was a noticeable service disruption from the user perspective, which was validated by starting an active data session on the device.

The connected-mode mobility between the two networks validates the MSO use case: the device transitioned to the MNO network when outside the MSO CBRS coverage area and transitioned to the MSO network when back inside the MSO CBRS network coverage area.

Idle Mode

The idle-mode thresholds, triggers, and observations for moving from the MSO network (higher priority) to the MNO network (lower priority) were similar to those discussed for HR. However, transition from the MNO network to the MSO network was performed using an HPPLMN search period, based on the assumption that an MSO will not have an MVNO agreement to control the idle-mode parameters configured on the MNO network. The minimum default value of the HPPLMN search period is defined in 3GPP as 6min, indicating that the transition from the MNO network to the MSO network will take more than 6min. For testing the HPPLMN search period timer, the “Enhanced LTE” option for VoLTE and cellular data were disabled. Keeping the device in idle mode with these two features enabled was a challenge because the device tends to periodically initiate updates and refresh applications in the background (every 40–50s).

Benefits and Tradeoffs

The LBO implementation is ideal for MSOs that do not have MVNO agreements with MNOs that allow sharing of roaming interfaces and provide control over mobility configuration. LBO will not offer seamless data session continuity in connected mode, and cell reselection in idle mode while moving from an MNO network to an MSO network would be a challenge.

The key benefits of an LBO implementation include

- efficient routing in terms of bandwidth and latency because the subscriber’s data are serviced by the visitor network and
- less dependency on an MNO network because only the S6a interface is shared and no mobility configuration is needed on the MNO network.

The tradeoffs of an LBO implementation include

- no seamless mobility in connected mode with no bearer context transfer via the S10 interface and
- noticeable service disruption while transitioning between networks with an active voice call (important if an MSO plans to deliver voice services with an LBO implementation).

Alternate Solutions to Network-Based Triggering

This section discusses two alternate solutions that could assist network transition without having to share roaming interfaces or make significant changes to network mobility configuration:

- controlling device mobility with external servers independent of the mobile core networks and
- making devices with dual-SIM capability smart enough to trigger transition from one network to the other without user intervention.

Device Transition Controlled with an External Server

Use of an over-the-top solution in which device mobility can be controlled by using an external server is one way to avoid significant changes on networks to assist with inter-operator mobility. This solution creates a logical tunnel between an external server and an application embedded on the user device. The embedded application is integrated with the connection manager within the device to override the inherent chipset and device algorithm. When the device has access to the internet and has reachability to the external server using either an MSO-owned Wi-Fi network, an MSO-owned CBRS network, or an MNO-owned LTE network, the external server and client can exchange information, and the MSOs can control the mobility policies for specific users, which are configured on the external server.

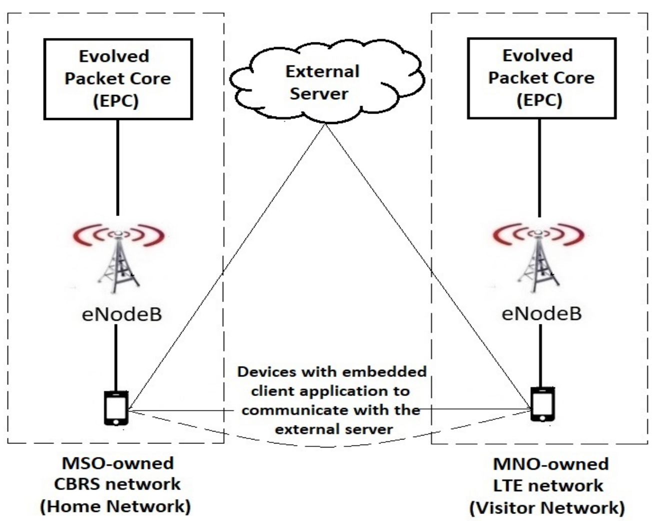

Figure 4: Device Mobility Controlled by Using an External Server

Figure 4 shows the implementation to control the device mobility by using an external server. This implementation addresses the MSO use case for having a device transition, in both connected and idle modes, to the MNO network when outside the MSO CBRS network coverage area and to the MSO network when back inside the MSO CBRS network coverage area.

When the external server overrides the device algorithm and transition mechanism, the mobility control is independent of the network triggers. The device transition can be made quickly enough to avoid any noticeable disruption to network connectivity from the user perspective. However, this solution does not offer seamless data session continuity while moving between the two networks; the two networks do not exchange messages to transfer the active bearer context. The solution benefits the MSOs in that they can control device mobility without needing MVNO agreements that include sharing of roaming interfaces and control over mobility configuration parameters on an MNO network.

Enhancing Dual-SIM Functionality

With the advent of shared spectrum, there is interest in exploring ways for devices to connect to multiple networks simultaneously. Although traditional phones have only one SIM slot to connect to a single operator network, dual-SIM phones (with either two SIM slots or one physical SIM slot plus one embedded SIM) can connect to multiple operators. Dual-SIM devices have been available for quite some time. The initial dual-SIM devices included dual-SIM single standby (DSSS) phones that could connect and actively use a single operator network at any given time. Recently, however, there has been an increase in dual-SIM dual standby (DSDS) devices, which can connect simultaneously to two networks. The device monitors both networks by time-sharing a single transceiver, allowing the user to dynamically choose which network and corresponding SIM to use.

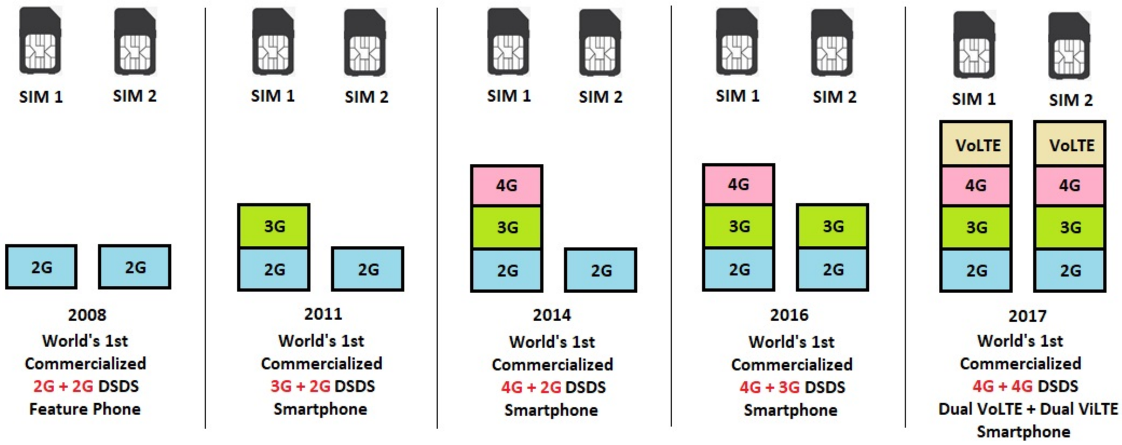

Figure 5: Dual-SIM Dual Standby Technology Enhancement[2]

Figure 5 shows the evolution of DSDS technology. With current DSDS phones, the user can be active on one network and receive paging from another. For example, if the user is performing an active data session on an MSO network and receives an incoming voice call on an MNO network, the dual-SIM device receives a paging signal to notify the user of the incoming call. With an active voice call on the MNO network, the data session on the MSO network is paused and continues when the voice call is terminated. However, with current DSDS implementations, there is no real-time data session continuity from one network to the other, and the user needs to manually switch between the two networks.

Enhancing the DSDS implementation to perform real-time and fast switching between networks based on power levels defined by the operators will address the MSO use case for having a device transition, in both connected and idle modes, to the MNO network when outside the MSO CBRS network coverage area and to the MSO network when back inside the MSO CBRS network coverage area without relying on an MNO to share interfaces or configure mobility parameters.

These observations are based on initial testing conducted by CableLabs using a small subset of dual-SIM devices. Additional testing of dual-SIM device capabilities will improve the understanding of current implementations and explore enhancements that can be added to current functionality.

Another implementation that could assist with inter-operator mobility is dual-SIM dual active (DSDA), in which devices can connect to and be active on two networks simultaneously. However, DSDA devices require additional hardware, i.e., separate radios, which could have an impact on device cost and battery life. Not many DSDA devices are currently available in the market.

The ability to make devices smart enough to switch between networks dynamically can be implemented at a chipset, model, or application level. Implementing device solutions at the application level provides MSOs more control in dynamically modifying triggers for specific users.

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[2] Data from "World's First Dual 4G SIM Solution with Dual VoLTE/ViLTE Support," August 2017, MediaTek

Conclusion

Different solutions can be implemented to achieve inter-operator mobility with CBRS. Each solution offers benefits that need to be weighed against certain tradeoffs. MSOs should adopt the implementation that meets their requirements based on their infrastructure ownership and MVNO agreements they have with MNOs.

The Home Routed (HR) implementation is ideal for an MSO that has a strong relation with an MNO such that sharing multiple interfaces and configuring mobility parameters is not an issue. HR benefits MSOs by enabling seamless mobility in connected mode for subscribers while transitioning between two networks, but it incurs high latency with user traffic being routed back to the home network.

The Local Break Out (LBO) implementation is ideal for an MSO that wants to have as little dependency as possible on an MNO and plans to offer only data services with CBRS. Offering voice services with LBO can degrade user experience because service disruption is expected during network transition without S10 interface sharing. LBO, however, offers efficient routing in terms of bandwidth and latency because user traffic is serviced by the visitor network.

Neither HR nor LBO, however, help MSOs that do not have MVNO agreements with shared roaming interfaces and control over RAN-based triggers for triggering connected- and idle-mode mobility. With no interface sharing and no control over mobility parameters on an MNO network, an MSO will have to rely on SIM configurations to connect to a higher priority MSO PLMN, which requires at least 6min to connect to an MSO network from an MNO network.

Understanding the requirements, benefits, and tradeoffs for each implementation can assist MSOs in determining what level of MVNO agreements are needed to implement a solution based on their requirements and infrastructure ownership. If none of the existing implementations seem to be a suitable solution, then alternate solutions need to be explored.

Alternative solutions include controlling device mobility with external servers and enhancing dual-SIM implementation to make devices smart enough to switch between multiple operators. MSOs should investigate these alternatives if they wish to minimize reliance on MNOs to share interfaces and configure mobility parameters.

The device and SIM implementations can be modified based on wireless operator needs, but they are defined in 3GPP to a certain extent. Nevertheless, there seems to be a scope for improving these implementations to better fit the needs of MSOs. CableLabs plans to explore these avenues to significantly improve inter-operator mobility between CBRS and licensed LTE networks while minimizing necessary changes to existing network infrastructure.