WiMAX FORUM® ROAMING MODELS WHITE PAPER

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1 Introduction

Roaming enables customers to automatically access their wireless services when traveling outside the geographical coverage area of their home network and can occur in many forms. The purpose of this document is to:

- Describe roaming and the various models used to provide roaming services; and
- Introduce some of the concepts and terminology adopted for WiMAX™ roaming.

It should be noted that this document is a white paper/tutorial document, not technical guidelines or a specification. It is stressed that there may be other roaming scenarios not addressed in this document and that readers are at liberty to choose the approach or approaches which best meet their individual needs whether or not described in this paper.

Roaming is a business and technical relationship, typically between two operators, that enables the subscribers of a home network to connect to and receive services through a second, or visited network. For example this includes internet, e-mail, voice, video and other services available on the home network.

When a subscriber uses a wireless device while moving, the device will try to attach to different access points when leaving the current coverage area. However, when the device used by the roaming user is outside the home network coverage area, the device will attempt to connect to an access point of a different network provider as long as a valid roaming arrangement is in place with the home operator.

Roaming provides significant advantages to customers and network operators. Roaming can dramatically expand the coverage area available to customers and enables an operator to expand its footprint without incurring additional network capital expenditures. Roaming may also provide additional revenue opportunities to network operators.

Roaming can be either terrestrial or non-terrestrial. Terrestrial roaming can be divided into national and international. National roaming occurs when the visited network is in the same country as the home network. International roaming occurs when the visited network is in a different country than the home network. Non-terrestrial roaming occurs when a user moves into coverage areas of operators governed by international laws, such as, maritime or satellite operators. This document will focus on terrestrial roaming.

From a wireless service provider's perspective, roaming consists of outbound and inbound roaming. From the perspective of a home wireless service provider, outbound roaming allows subscribers of the home wireless service provider to access services on visited networks. From the perspective of a visited network, inbound roaming allows subscribers of home wireless service providers to access its network (or a network it has access to through a Network Access Provider – see below). The money flows relating to roaming are typically as follows: A home wireless service provider (defined as the Home Network Service Provider or HNSP for WiMAX) receives revenue from its subscribers for roaming services the subscribers receive and the HNSP pays the visited network operator (Visited Network Service Provider or VNSP for WiMAX) for use of the VNSPs network by its subscribers. WiMAX roaming is a technical and a business relationship between two different WiMAX Network Service Providers (NSPs).

A NSP is a business entity that provides IP connectivity and WiMAX services to WiMAX subscribers. To provide these services, an NSP establishes contractual agreements with one or more Network Access Providers (NAP). An NSP may also own and operate its own NAPs. A NAP is a business entity that provides WiMAX radio access infrastructure to one or more NSPs. An NSP may also establish roaming agreements with other NSPs and contractual agreements with third-party application providers (e.g., ASP or ISPs) for providing WiMAX services to subscribers. For WiMAX roaming, a Home Network Service Provider (HNSP) is a Service Provider that has subscribers which obtain access to a second operator's network through a roaming agreement between the HNSP and a Visited Network Service Provider (VNSP). The VNSP is the provider of roaming access / services to subscribers of the HNSP. [1]

The diagram below displays the interconnections required between a HNSP and VNSP to enable roaming.

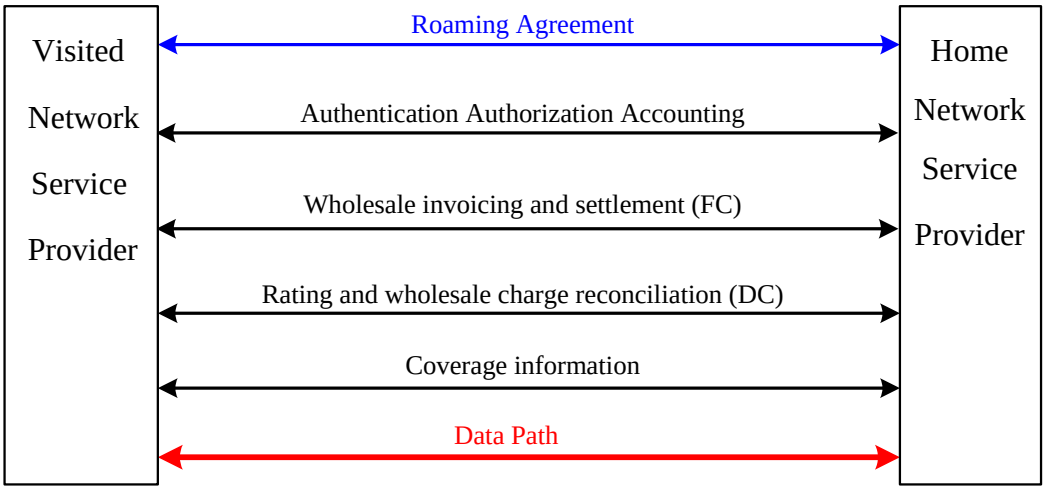


Figure 1 Roaming Interconnections

For roaming to occur, the networks of two NSPs are normally connected to:

• Provide access to service.

• Enable the process of sharing usage information.

• Facilitate billing and financial settlement between operators.

From a technical perspective roaming entails several functions. When a user accesses service through a roaming partner (VNSP) the device must discover and select the VNSP that it will connect to for services. The device and/or user must be authenticated and authorized to use services prior to the VNSP granting access to its network for services. Authentication is a process by which the HNSP validates that the device and/or user is a subscriber of the HNSP while authorization verifies whether the roaming user is eligible for roaming services on the VNSP network. Authentication occurs through communication between the HNSP and VNSP AAAs. Roaming also requires that usage be tracked and agreed to by the HNSP and VNSP and that financial invoices are generated and payment is made between the NSPs for the use of each other's networks.

To facilitate roaming between WiMAX operators, the WIMAX Forum® is standardizing the signaling, rating, clearing and financial settlement interfaces for WiMAX to WiMAX roaming through the WiMAX Roaming Interface (WRI) specifications. [2]

The roaming concept and the associated functional interfaces to enable roaming are technology independent. The above description of roaming is, at a high level, the same for WiMAX, Wi-Fi, GSM and CDMA.

Roaming can also occur between networks using differing technologies, such as WiMAX and Wi-Fi or WiMAX and GSM/CDMA. Roaming between technologies requires interworking. Interworking is defined by the WiMAX Forum as a technical and business relationship between a WiMAX network and a non-WiMAX network (either the Access Network or the Core Network could be non-WiMAX) that enables the subscribers of the first network (home service provider) to connect and receive services in the second (visited or serving network). The WiMAX and non-WiMAX networks may be owned by the same entity or different entities. Roaming occurs when the WiMAX and non-WIMAX networks are owned by different entities. [1]

2 Roaming through a 3rd party exchange

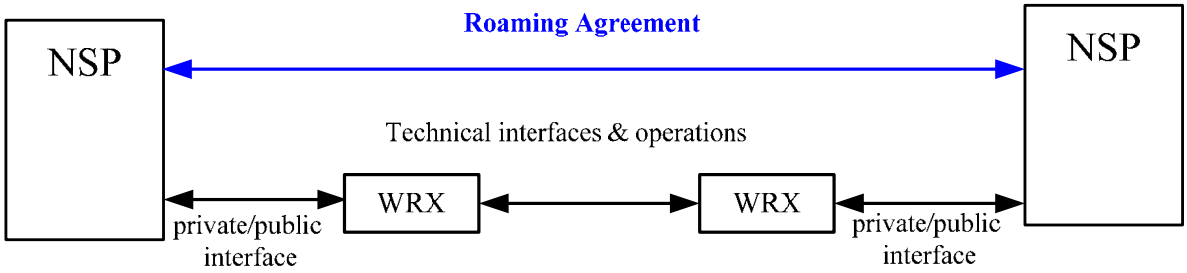


Figure 2 Interfaces between home and visited Network Service Providers

To facilitate roaming between wireless operators, industry associations standardize the roaming interfaces and provide specifications for those interfaces. A public interface is an implementation of roaming that complies with an established standard. The WiMAX Forum® is establishing specifications for a public interface known as the WiMAX Roaming Interface (WRI). [2] By comparison, a private interface is an implementation of a proprietary roaming interface that may not comply with an agreed standard. A private interface is the result of an agreement between two entities on how to inter-operate according to a proprietary specification.

Two or more operators may connect with each other through one or more intermediaries known as Roaming Exchanges (WiMAX Roaming Exchange (WRX) for WiMAX roaming) for bilateral or unilateral roaming (see Section 3 for discussion of bilateral and unilateral roaming). The diagram above depicts a bilateral roaming relationship between two Network Service Providers (NSP) connected to each other via WRXs. In this scenario each NSP has contracted with a WRX to support the roaming service. The NSPs may also connect directly with each other to provide roaming services. In such a situation, WiMAX NSPs may support the WRI. NSPs commonly use a private interface for connecting to the WRX (and in some cases for connecting with each other directly) as depicted in the diagram. However, WRXs are expected to implement the public interface with other WRXs and WiMAX NSPs.

As illustrated below, an advantage of connecting through a third party provider is that it can enable an NSP to connect with many other operators through a single connection. This can allow an operator to expand its footprint quickly and reduce the need to establish many direct connections with other operators.

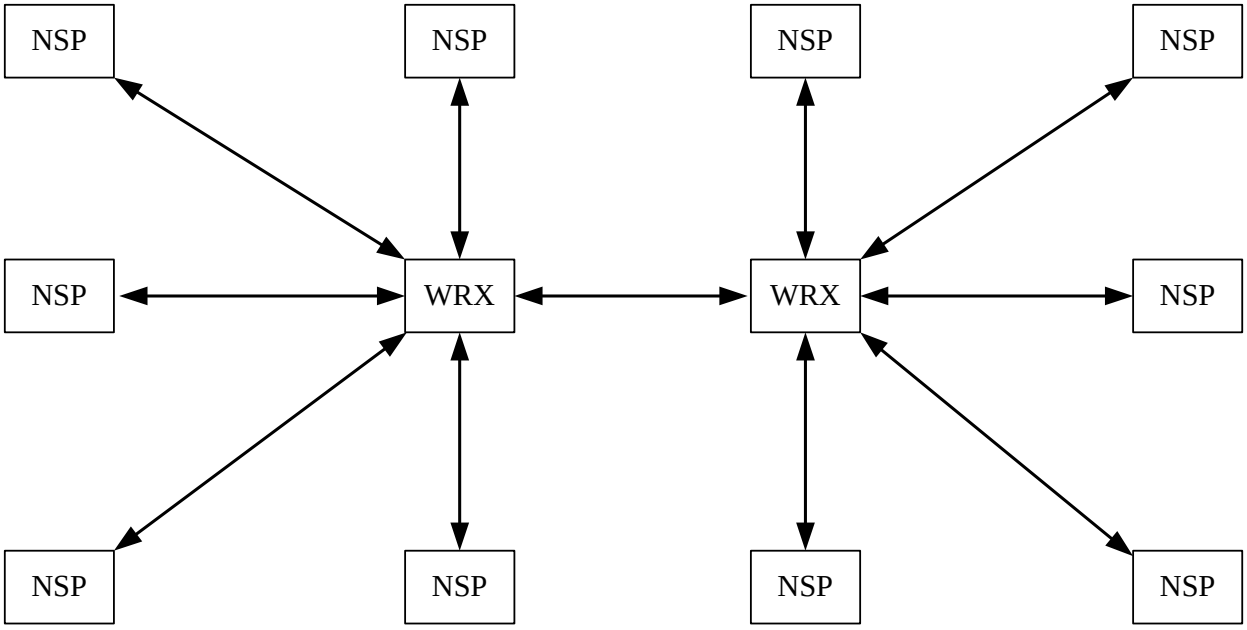


Figure 3 Example of WiMAX Roaming Exchange Relationships

Services provided by a roaming exchange include:

- Authentication support
- Wholesale rating
- Financial clearing and settlement
- Invoice creation
- Fraud management
- Roaming contract management (on behalf of the operator)
- Bearer traffic routing

Operators may outsource a portion or all of these services to one or more WRX providers.

NSPs may use the services of a WRX to handle specific functions while maintaining a bilateral roaming relationship with other NSPs, Hub Providers or Aggregators (see below). NSPs may also act as a WRX for other NSPs.

3 Roaming models

Roaming services can be provided using a variety of models that imply different business relationships and technical implementations. All roaming models described in this document can be used to support outbound and/or inbound roaming.

3.1 Bilateral roaming

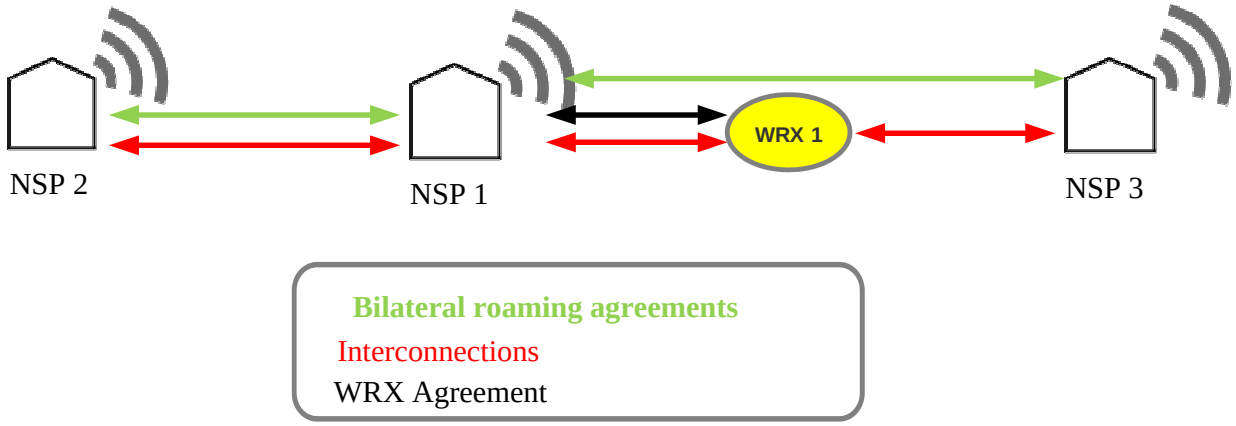
Bilateral roaming occurs when subscribers of two NSPs roam onto each other's networks (or networks the VNSPs have access to through NAPs). For bilateral roaming, two NSPs establish a roaming agreement with each other. The NSPs may have a direct connection and handle all of the roaming functions on their own. Alternatively, one, or both, of the NSPs may outsource some or all of the roaming functions to a third party WRX as described in the previous section. In this case an NSP will have a roaming agreement with the second NSP and a WRX agreement with a WRX provider.

In a bilateral roaming model, the HNSP is always liable to the VNSP for the traffic that the HNSP's subscribers generated on the VNSP's network. Also, for WiMAX, a VNSP may contract with a third party NAP for radio access.

One benefit of a bilateral roaming relationship is that it can provide greater NSP control over many or all aspects of roaming, particularly when an NSP handles all technical and business aspects of the roaming relationship. When there is a high volume of traffic between NSPs direct connections are common. However, bilateral relationships can require significant resources for contract negotiation and management, technical implementation and ongoing operations, customer care, financial clearing and settlement and fraud management. Implementing a large number of bilateral contracts and direct connections can require a considerable amount of time and resources for implement and ongoing operations.

The following figure depicts bilateral roaming between NSP1 and two other NSPs. NSP1 has a direct physical connection with NSP2 and a physical connection with NSP2 through its WRX provider, WRX1.

Figure 4 Bilateral Roaming Agreement



3.2 Unilateral roaming

Unilateral roaming occurs when subscribers of one NSP roam onto the network of a second NSP, without reciprocity. This can occur when the HNSP provides wireless services to subscribers but does not operate a network itself. Unilateral roaming relationships are also common when there are two technologies involved. Other reasons for unilateral roaming include commercial, resource and technology issues. As a

part of establishing unilateral roaming, two NSPs establish a roaming agreement reflecting the unilateral nature of the relationship.

The benefits of unilateral roaming include an increase in coverage area for the HNSP and additional revenue opportunities for the VNSP through traffic generation on its network.

A unilateral roaming agreement is established between a HNSP and a VNSP. The HNSP is liable to the VNSP for the traffic its subscribers generate on the VNSP's network.

An example of unilateral roaming is as that of a VoIP service provider that would like to provide a worldwide VoIP service using WiMAX technology. The VoIP service provider retails its services to its subscribers and is, therefore, a HNSP. The VoIP service provider might, however, not operate a WiMAX network itself, and through unilateral roaming agreements with established WiMAX NSPs, is able to offer roaming access in its local market as well as in different countries for the users of its VoIP service.

In the figure below, subscribers of the HNSP roam onto the VNSP network without reciprocity. Note: The physical connection between the HNSP and the VNSP may be either direct or through a WRX (or two WRXs if both NSPs use WRXs).

Figure 5 Unilateral Roaming Agreement

3.3 Hub model

The Hub Model is a business and technical construct which allows NSPs to roam with each other using Roaming Hub Providers (Hub Providers) as intermediaries. With this model NSPs do not have a direct contractual relationship with each other. Rather, NSPs contract with one or more Hub Providers to provide roaming services for their subscribers on VNSP networks (or networks the VNSP has access to through NAPs) with which the Hub Providers have relationships, either directly or through other Hub Providers. The contractual agreement between an NSP and a Hub could allow the NSP to act as a VNSP, a HNSP or both. Hub providers are encouraged to interconnect with each other to provide ubiquitous roaming services to the operators they support. To ensure quality of service, there may be practical limitations to the number of third parties which can be in the path between the home and visited NSP.

Many Hub Providers operate a roaming exchange (e.g. WRX) to connect NSPs as part of their Hub services. It is, however, possible that some Hub Providers may outsource a portion or all of the roaming exchange services to a third party. In order to connect with other NSPs using the Hub Model, an NSP establishes a connection with a Hub Provider, directly or via a roaming exchange. Note that there could be a series of connections between roaming exchanges of the NSP and Hub Provider. This will not be addressed in this white paper.

In the figure below the Hub Providers connect NSPs with other NSPs and operate their own WRXs to connect networks. They may also connect WiMAX NSPs with non-WiMAX networks. An NSP might not operate a network as depicted by NSP 3 in the figure below.

Hub Model: Business Relationships and Interconnections

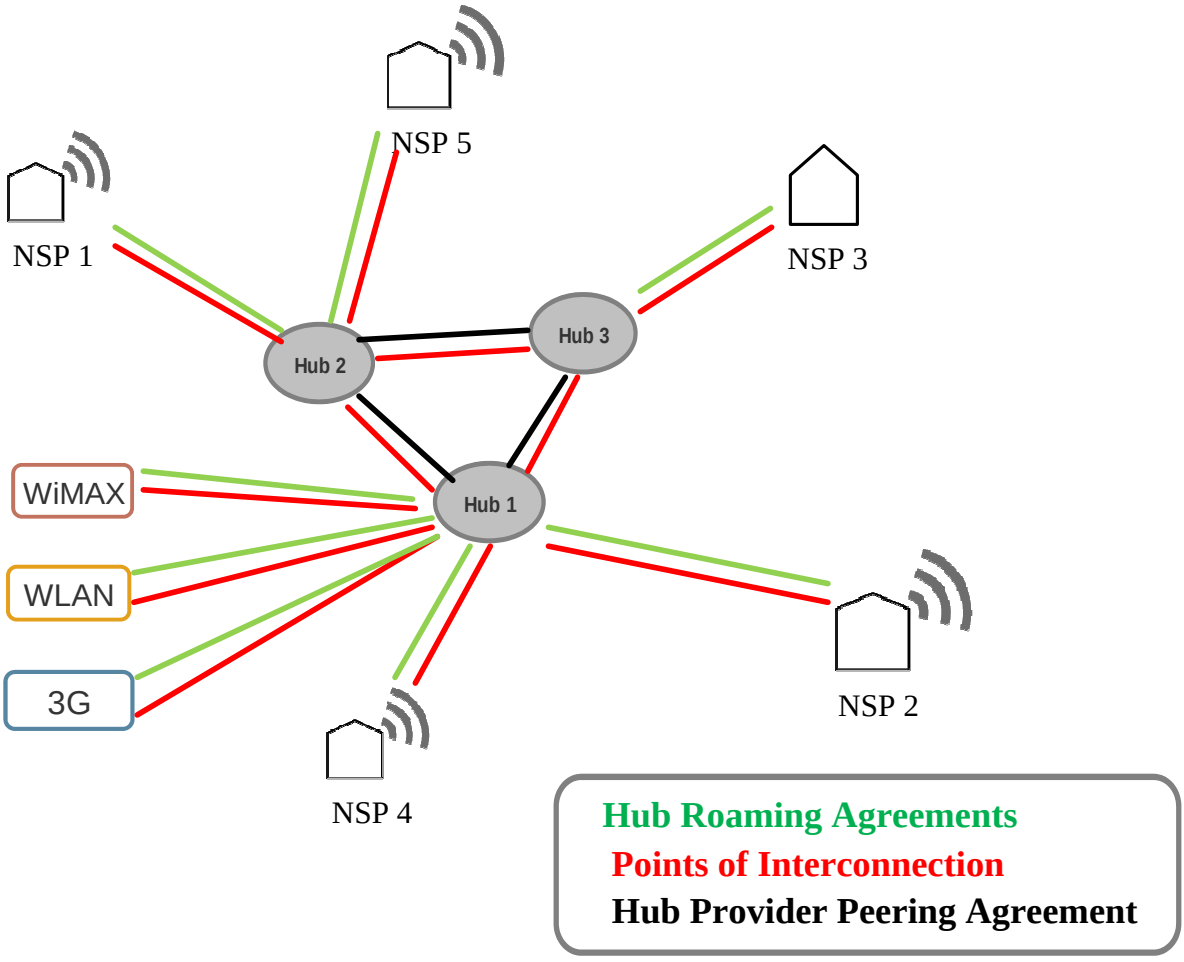
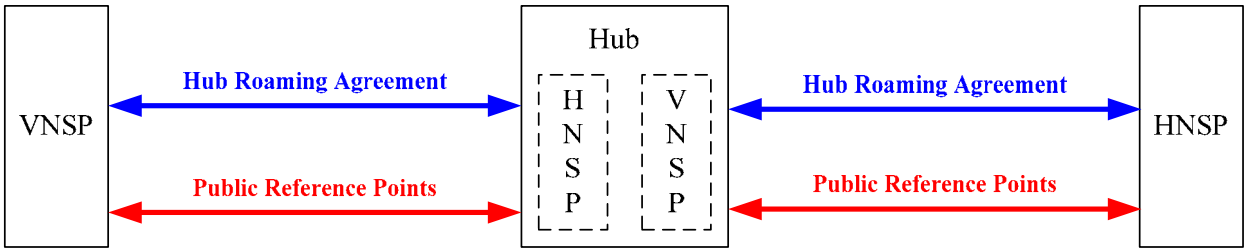


Figure 6 Hub Model: Business Relationships and Interconnections

Hub Providers are virtual network service providers in as much as they are reselling to HNSPs roaming access to VNSPs. Contractual relationships are between Hub Providers and HNSPs/VNSPs. Hub Providers are contractually and financially liable to HNSPs and VNSPs with this model. Likewise, HNSPs and VNSPs are contractually and financially liable to Hub Providers and not to other HNSPs or VNSPs. Hub Providers collect payments from an HNSP and make payment to the VNSP for use of its network by subscribers of the HNSP. Also, Hub providers are responsible for ensuring and enforcing terms of any Service Level Agreements (SLAs) with NSPs.

The Figure below depicts the basic Hub Model with Hub Roaming Agreements. The Hub acts like a HNSP for the VNSP by providing subscribers to roam onto the VNSP network. Likewise, the Hub acts like a VNSP for the HNSP by providing access to networks for the HNSP subscribers.

Figure 7 Hub Roaming Agreement and Public Reference Points



A Hub Provider can provide roaming services using the same or a different technology than that of the HNSP. For example, if the HNSP is a WiMAX operator, the Hub Provider may provide roaming onto Wi-Fi networks for subscribers of the HNSP, and this, without the need for the WiMAX NSP to establish direct roaming agreement with Wi-Fi operators.

It should be noted that an entity can be both a HNSP (i.e., provide outbound roaming to its subscribers) and a VNSP (i.e., provide inbound roaming to subscribers of other NSPs). A Hub Provider may also be an NSP.

The Hub Model can enable an HNSP to quickly acquire a roaming footprint without the need to establish roaming agreements with a large number of operators. Also, for a VNSP, the Hub Model represents an opportunity to quickly garner additional usage on its network from multiple NSPs through a single agreement with a Hub Provider. Hub Providers can build a large roaming community within the framework of a single agreement between each NSP and a Hub Provider. It is in the interest of Hub Providers to actively grow this community.

The Hub Model can potentially bring fast growth and scale to roaming. Each new interconnection between a Hub Provider and a NSP results in the potential for additional roaming between the new NSP and the entire community of NSP members versus only one new roaming relationship that is created with a new bilateral roaming agreement. For example, if a Hub network consists of 20 NSPs that are part of a Hub network, the next NSP/VSP that interconnects with a Hub Provider may result in 20 potential new roaming interconnections as opposed to only one when a HSP establishes a new bilateral roaming interconnection.

The use of the Hub Model may impact the level of control a NSP has over its roaming relationships although access to its network and its subscribers' access to other networks can be adequately addressed in the contract with the hub provider.

The Hub Model has implications on the roaming interfaces. The Hub Provider participates in the signaling, rating, clearing and financial settlement flows. To support the Hub Model, specifications for bilateral roaming must be adapted to include a third (or more) hop in the flow. Any modifications may require that signaling transparency be maintained so that an HNSP knows which VNSP is the originator of authentication and accounting requests.

Figure 7 above depicts the public reference points between a Hub and NSPs.

4 Other wireless business models and roaming

Aggregator:

The term Aggregator is currently primarily associated with Wi-Fi in the form of Wi-Fi hotspot network aggregation. The aggregator model is a form of the Hub Model. The purpose of this Section is to describe the Aggregator concept as it currently applies to Wi-Fi since it may also be used for WiMAX roaming.

For Wi-Fi, an Aggregator is an NSP that purchases access to Wi-Fi hot spots from the access point owner for use by customers of the Aggregator. The Aggregator enters into a roaming agreement with the Wi-Fi access point owner for the use of its network. The Aggregator is a virtual network operator to the extent that it uses the network of another operator / access point provider. An Aggregator may also own some of the network / hot spots it makes available to its customers.

Aggregator customers may be individuals, or companies which provide their employees with broadband wireless access via the Aggregator. Aggregators offer a variety of customer plans for broadband access. These can include unlimited use and casual per day, per hour and per minute plans. Plans range from local, nationwide or global access. Roaming may or may not be included in the rate plan. The agreement between the network aggregator and the network owner is a wholesale agreement for network access and is considered a roaming agreement by the Wi-Fi industry.

Aggregators may also provide access to NSPs on a wholesale basis to provide Wi-Fi access for the NSP's customers.

Mobile Virtual Network Operator (MVNO):

The MVNO model is broadly used in the cellular industry. Roaming for MVNOs is similar to roaming described in previous sections.

MVNOs typically provide wireless services to their customers by accessing the network of a single operator (Host Network Operator) based on an MVNO agreement. To a Host Network Operator, an MVNO represents a reseller of access to its network. In the cellular industry an MVNO may or, may not, have its own Home Location Resister (HLR), the equivalent of which is the AAA for the WiMAX network.

The contract between the MVNO and the Host Network Operator is a wholesale agreement, but is not referred to as a roaming agreement within the cellular industry. Typically, the wholesale charging mechanism for access is a per minute rate for voice and a per kilobyte rate for data. MVNOs are typically responsible for retail sales and distribution, retail billing, customer care and product and device management. The Host Network Operator's role is often limited to providing network access.

An MVNO may offer roaming services to enable its subscribers to access services beyond the Host Network Operator's network. This is typically achieved by piggy-backing on the Host Network Operator's roaming network. For roaming services, the Host Network Operator charges the MVNO for roaming access. As an alternative to piggy-backing on the Host Network Operator's roaming network, an MVNO may choose to negotiate and enter into its own roaming relationships with VNSPs to expand coverage beyond the area provided by the Host Network Operator's network. This latter option is generally only possible if the MNNO operates its own HLR.

NAP Sharing

NAP sharing refers to a particular type of deployment of a WiMAX network in which a single NAP (Network Access Provider) which owns and operates an Access Service Network (ASN), connects to multiple NSPs. The NSPs share the radio infrastructure of the NAP to provide their subscribers with access to WiMAX services.

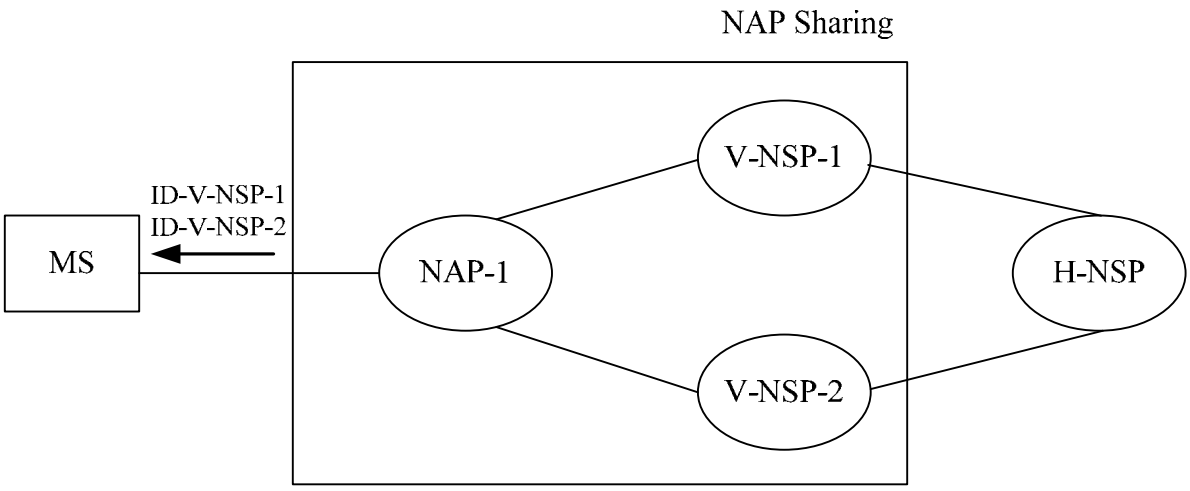


Figure 8 Simple WiMAX NAP Sharing Scenario

This model is similar to the MVNO concept described above. It is foreseen that NAP sharing may be used by an NSP to create a pan-regional network (i.e. a network that covers several regions or several countries). The business relationship between the NAP and the NSP is not considered as a roaming relationship, although it has very similar characteristics. The WiMAX Forum® defines "roaming" as the technical and commercial interface between a VNSP and an HNSP. The WiMAX Forum has standardized the signaling interface between the NAP and the VNSPs.

The Hub Provider model could also apply to NAP sharing, whereby the Hub Provider connects NAPs to VNSP/HSNPs. The Hub Provider would act as a visited NSP from a wholesale and accounting perspective. Interfaces needed to support NAP sharing to a Hub Provider have not been provided in the current WiMAX Forum Network Architecture [3] or the WiMAX Forum Roaming Interface [2]. The architecture would need to be updated to include interfaces to support NAP Sharing to a Hub Provider.

The figure below depicts NAP sharing through Hub Providers. In this scenario Hub Providers have agreements with NAPs and NSPs and link them together.

NAP Sharing Through Hub Providers

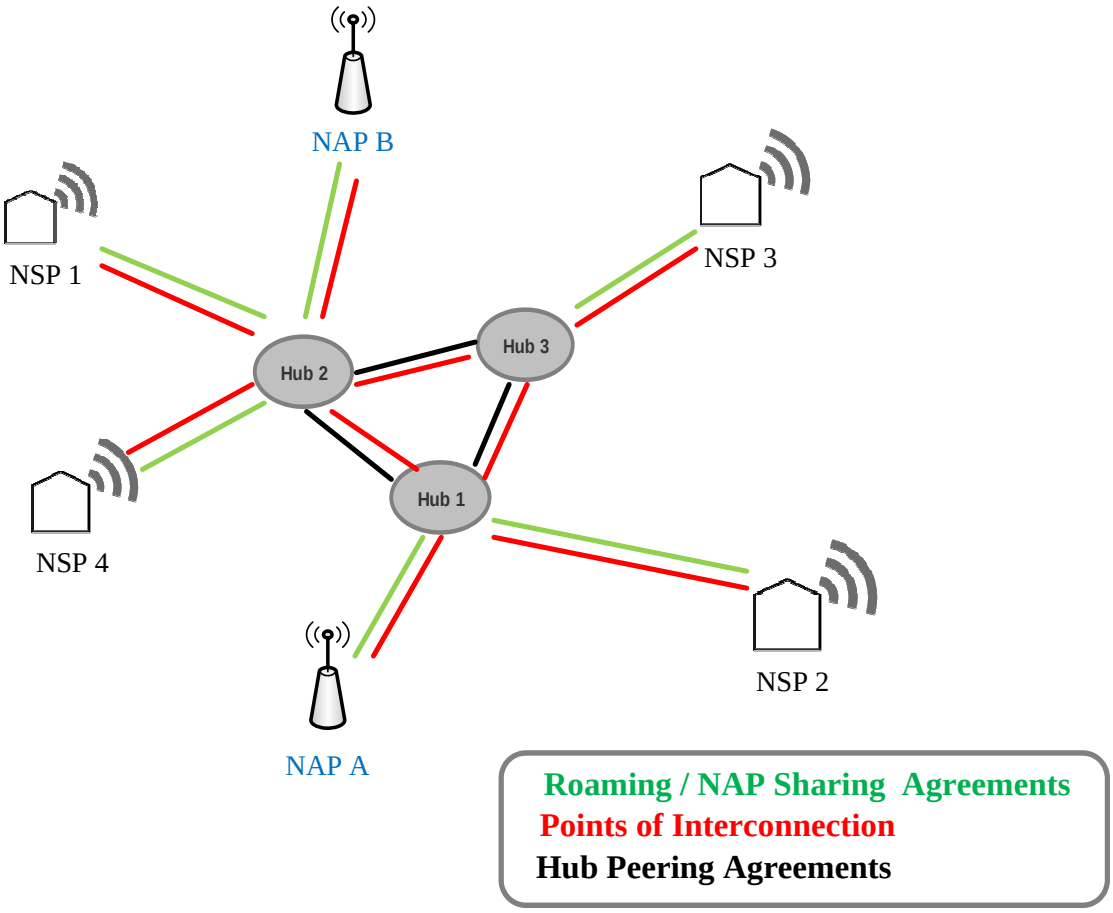


Figure 9 NAP Sharing Through Hub Providers

5 Roaming mix

A small percentage of the roaming relationships may produce the majority of the roaming traffic in a network. An HNSP often establishes hundreds of roaming relations to market their service and remain competitive.

The corollary is that the vast majority of roaming relations bring incremental revenues to an operator. While an operator may establish bilateral roaming agreements for its high usage roaming relations, the Hub Model may also provide a cost effective and less resource intensive means of acquiring access to a global footprint.

The models presented in this paper are by no means exclusive. Each operator, based on its roaming needs and roaming usage patterns on its network, can optimize the mix of its roaming relations.

6 Conclusion

For customers, roaming provides a broader area in which they can access their services. For a NSP, roaming represents the extension of its coverage area outside of its home network. Roaming also represents new revenue opportunities for VNSPs as their networks are opened up to a broader user base. NSPs which choose to provide services outside of their home network or to allow access to their home network by subscribers of other NSPs have a variety of business models to choose from. Their choice depends on their business needs. The roaming models described in this document are complementary and will continue to co-exist. It is important that WiMAX roaming be available using any of these models.

7 References

[1] WMF-T31-001-R010 WiMAX Forum® Recommendations and Requirements for Networks based on WiMAX Forum Certified™ Products.

[2] WMF-T42-001-R010 WiMAX Forum® WiMAX™ Roaming Interface based on WiMAX Forum Certified™ Products Stage 2 Release 1.0.

[3] WMF-T33-001-R010 WiMAX Forum® "Network Architecture Release 1.0".