Wireless Strategies Beyond Wi-Fi for Fixed Network Service Providers

April 26, 2016

1 BACKGROUND

Fixed access network service providers[1] are witnessing increasing competition in their TV and broadband businesses. In response, many MSOs have started offering residential, enterprise and Wi-Fi hotspots as a value-added service and as an enabler for churn reduction. Some MSOs, such as Cablevision (U.S.), are using their Wi-Fi footprint to launch limited "wireless" services, while others such as Ziggo (Netherlands) have added cellular wireless services by becoming a full Mobile Virtual Network Operator (MVNO). Wireline and fiber access providers are investigating using wireless services to increase customer stickiness and grow revenues. In addition, the Internet of Things (IoT)[2], with potential for billions of new wireless devices ultimately connected to "wires", will create opportunities for service providers with licensed or unlicensed wireless footprint.

A wide range of strategic options are available for providing "wireless" services regardless of whether or not the service provider has licensed spectrum. Figure 1 illustrates these options and corresponding potential revenue opportunities.

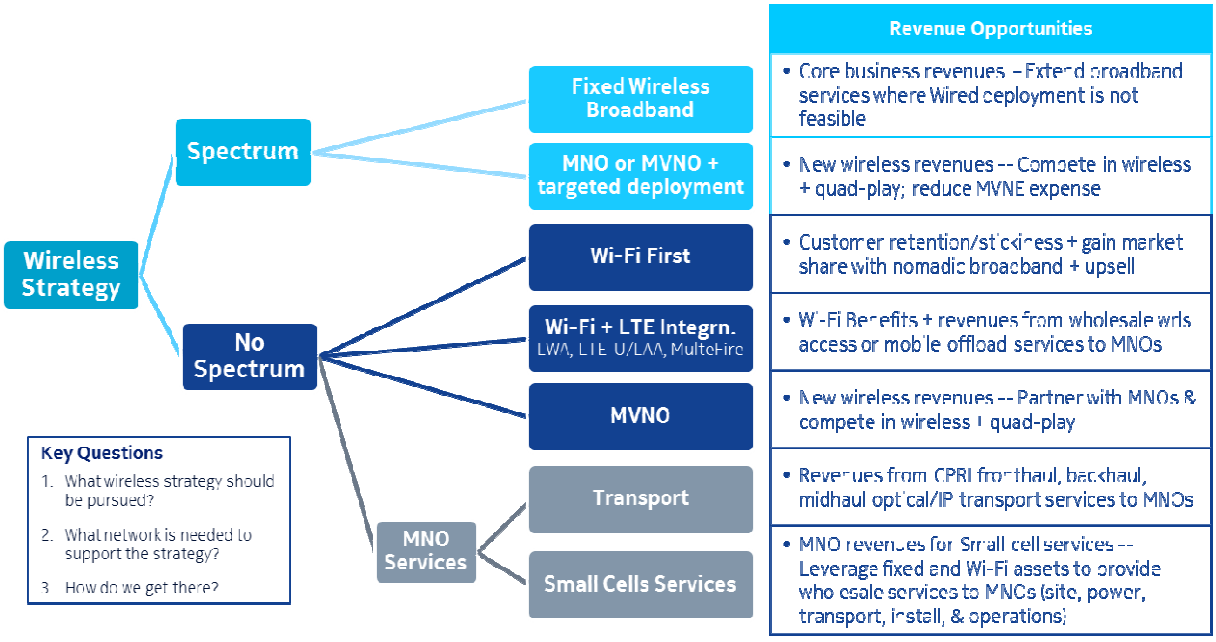

Figure 1: Wireless Strategic Options

[1] Includes Multi-System cable Operators (MSOs) and fixed wireline access providers.
[2] Both licensed and unlicensed spectrum can be used to provide wireless IoT connectivity. Details of IoT are not provided in this paper.

This paper addresses the three key questions posed in Figure 1. Section 2 addresses question 1 by presenting an overview of several wireless strategy options that can be pursued by service providers, and related technology enablers. Section 3 addresses questions 2 and 3 by presenting an overview of the key network requirements and architecture dimensions that must be considered to enable future wireless strategies. Determination of which strategy or combination of strategies a service provider should pursue, the network required, and the plan to get there, requires a detailed analysis comprised of a blend of scenario planning, market analysis, business modeling and network modeling.

2 WIRELESS STRATEGIC OPTIONS

2.1 Options without Licensed Spectrum

2.1.1 Wi-Fi First

Customers value the freedom to extend their fixed access broadband service to a nomadic environment. Surveys have shown that while a majority of the Wi-Fi usage is at home and work, consumers everywhere use Wi-Fi in public places. To reduce churn and provide value-add to their subscribers, service providers globally have widely deployed Wi-Fi in public and private locations. However, there is a desire to further monetize those investments. In addition to Wi-Fi access for their broadband users, some service providers are using their large public Wi-Fi footprint to provide inexpensive nomadic "wireless" voice & texting services via smartphones. Target customers are those who are value conscious and do not need the extended reach and high quality of cellular voice networks. They offer "Wireless" Voice over Wi-Fi (VoWi-Fi) and Data Services, termed Wi-Fi First[3] which refers to mobile devices and services that use Wi-Fi as the primary wireless network, with fallback to cellular networks.

Service providers have used a combination of residential, community, enterprise, and public hotspots for their Wi-Fi deployment strategies. Some service providers have supplemented their own Wi-Fi deployments with partnership strategies to expand not only local & national access but to also provide international Wi-Fi roaming. In the U.S., many service providers have teamed together to allow nomadic roaming of customers onto each other's Wi-Fi networks with a single registration process.

2.1.2 Wi-Fi + LTE Integration (LWA/LWIP, LTE-U/LAA, MulteFire™)

Consumer acceptance of Wi-Fi is high, but consumers find the performance inconsistent due to congestion and limited range, as well as others reasons. Access Network Discovery and Selection Function (ANDSF[4]) & Hotspot2.0[5] are two key technologies that may improve the

[3] www.wififirst.com

[4] ANDSF -- A cellular technology 3GPP standard that allows an operator to provide the UE a list of preferred access networks and maps of available access networks

consumer Wi-Fi experience by providing the ability to switch from cellular to Wi-Fi, and back again. However, neither of these technologies enables blending of Wi-Fi with cellular technologies to provide the best possible experience. Cellular technologies provide efficient spectrum usage for voice and data services. However, this spectrum may be difficult and expensive to acquire. An enhanced quality of experience (i.e. throughput, latency, range, etc.) can be achieved by blending and simultaneously accessing cellular and Wi-Fi networks. Three of these blending technologies are discussed below.

2.1.2.1 LWA and LWIP

LTE-WLAN Aggregation (LWA) and LTE-WLAN Radio Level Integration with IPsec Tunnel (LWIP), as standardized in 3GPP, enables mobile devices (UEs) to utilize LTE and Wi-Fi technologies simultaneously for an improved end-user experience, increased capacity, range, and peak data rates. With LWA, uplink traffic is shifted to an available LTE channel while downlink traffic can be carried over LTE and/or Wi-Fi. With LWIP, uplink and downlink traffic can be carried over LTE or Wi-Fi, but not simultaneously over both channels.

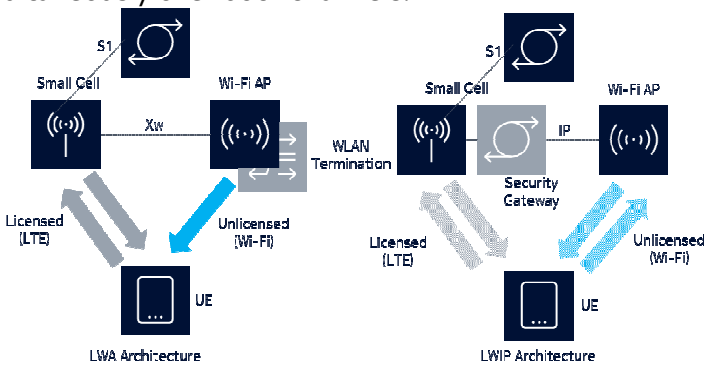

Figure 2: LWA and LWIP Architecture[6]

These technologies can provide multiple benefits to service providers including:

- >10X higher uplink throughput for Wi-Fi users connected simultaneously to LTE
- 2X application coverage range of a Wi-Fi access point experiencing high-traffic
- More consistent end-user experience
- Up to 70% increase in download speeds compared to standalone Wi-Fi
- Two times downlink gain over standalone LTE

Service providers can leverage these capabilities to offer higher quality and cost effective retail mobile services to its customers by integrating licensed spectrum (either through an MVNO partnership with a wireless service provider or acquisition of licensed spectrum). Alternatively, increased capacity of installed Access Points (APs) can help in delaying new Wi-Fi

[5] Hotspot2.0 -- Wi-Fi Alliance technology standard that allows mobile devices to more easily: a) Discover Wi-Fi roaming relationships; b) Determine access point capabilities and loading conditions, and; c) Make secure connections to Wi-Fi networks

[6] WLAN Termination (WT) - Logical node for interworking between LTE and Wi-Fi, Xw – Direct interface between LTE eNB and WT as standardized by 3GPP

deployments especially at capacity constrained or low signal locations. These technologies could potentially improve the Wi-Fi deployment business case through capex reduction due to incremental deployments, reduced traffic carried by the Mobile Virtual Network Enabler (MVNE)/MNO, and higher revenue potential due to higher quality of end-user experience.

A variation on the business model enables service providers to leverage an existing base of Wi-Fi APs including backhaul and installed infrastructure to offer 'Wi-Fi as a Service' to wireless service providers. These technologies can provide competitive differentiation to a service provider and stimulate monetization of excess capacity of Wi-Fi installed base.

2.1.2.2 LTE unlicensed (LTE-U, LAA)

"LTE unlicensed" brings the quality of commercial LTE technology to the unlicensed spectrum. LTE-U is a term that covers all implementations of LTE in the 5 GHz unlicensed band that use a licensed channel for signaling to coordinate transmission among different channels. Regardless of how it's implemented, it is fully integrated within LTE networks and it acts as a secondary channel that relies on Carrier Aggregation (CA). It delivers LTE-Advanced (LTE-A) signaling protocols across unlicensed spectrum bands (5 GHz) for enhanced capacity, almost triple the Downlink (DL) speeds compared to licensed small cells alone, and improved cellular network performance. However, because it does not implement Listen-Before Talk (LBT) mechanisms, there are ongoing debates around possible interference and ability to co-exist with Wi-Fi in unlicensed spectrum. LTE-U can only be used in markets where regulation does not require LBT, such as China, Korea, India and the U.S.

Licensed Assisted Access (LAA) is the version of LTE unlicensed that the 3rd Generation Partnership Project (3GPP) has recently standardized as part of Release 13 and that supports LBT in addition to CA. It is designed to enable effective and fair coexistence with other technologies including Wi-Fi in unlicensed spectrum. While current specifications are limited to unlicensed spectrum being used for DL transmissions only, the next release (due in June, 2017) will allow Uplink (UL) transmissions in unlicensed spectrum as well.

LAA aims to achieve higher spectral efficiencies in the presence of interference and can provide better spectral efficiency than Wi-Fi in unlicensed spectrum. This leads to LAA providing higher capacity and extended coverage resulting in reduced TCO for network deployments.

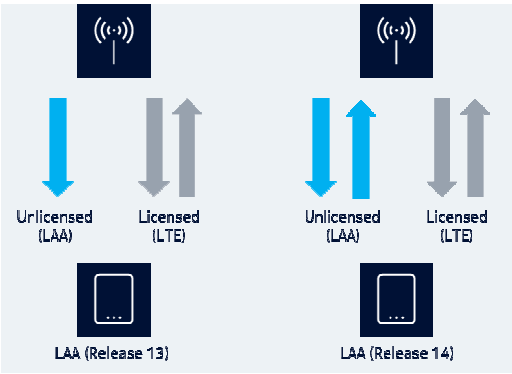

Figure 3: LAA Modes

Since LTE-U/LAA technology requires licensed spectrum and co-located licensed and un-licensed spectrum based small cells, service providers have the opportunity to create partnerships with MNOs for pure play strategy or for a business model that benefits both the service provider and MNO.

2.1.2.3 MulteFire

LTE-Unlicensed (LTE-U or LAA) and LTE WLAN Aggregation (LWA or LWIP) require the service provider to have access to licensed spectrum, thereby limiting potential use cases. MulteFire[7] (MF) is a new LTE based technology that solely operates in unlicensed spectrum and doesn't require an 'anchor' in licensed spectrum. MulteFire brings LTE-like performance to unlicensed spectrum with the simplicity of Wi-Fi like deployments. Like LAA, it includes LBT among other techniques to enable fair coexistence with Wi-Fi.

MulteFire provides service providers with capabilities to offer LTE-like nomadic access over unlicensed spectrum by leveraging their key assets including backhaul, physical locations and customer base. LTE's greater coverage and higher spectral efficiency provides advantage over Wi-Fi in terms of reduced TCO for incremental capacity and coverage. MulteFire provides an excellent opportunity to provide wireless access services to enterprises, clusters of residences and high-traffic venues including shopping malls, transportation hubs, sporting arenas and outdoor hotspots.

Service providers could use MulteFire to offer neutral host services where either nomadic wireless access can be provided in a SIM-less subscription model for consumers, or in partnership with multiple MNOs to offer Subscriber Identity Module (SIM)-based mobile offload services. Neutral host services need additional investment for MulteFire specific Evolved Packet Core (EPC) to provide IP services.

2.1.3 MVNO

Service providers can provide cellular mobile services without owning spectrum or infrastructure by leasing capacity from a "host" MNO. There are a range of MVNO business models from a branded reseller to a Full MVNO as depicted in Figure 5. An MVNO's network architecture will follow the choice of the business model - the two cannot be disconnected.

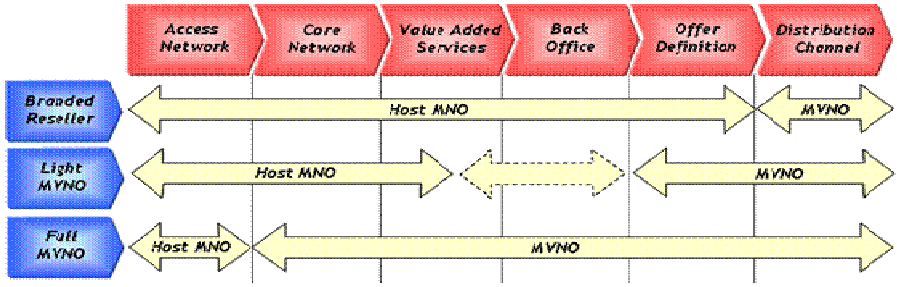

Figure 4: MVNO Business Models

[7] MulteFire is promoted through MulteFire Alliance that was founded in October 2015 by Nokia and Qualcomm.

Historically, the business case for MVNOs was challenging because it depended largely on the rates negotiated with MNOs and limited opportunities existed to reduce costs. However, service providers can now provide wireless services with improved economics by combining the technologies described in sections 2.1.1 and 2.1.2 with an MVNO strategy. Conceptually, a service provider can reduce cost and potentially offer a lower price service than a historical MVNO due to a reduced cost per bit with Wi-Fi compared to wholesale cellular rates as depicted in Figure 5[8]. Alternately, they can resell Wi-Fi/LTE-U capacity to other MVNOs who do not have these capabilities.

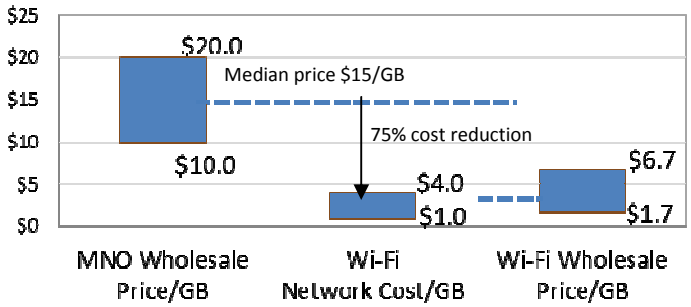

Figure 5: Wi-Fi vs. Mobile Wholesale Rates

2.1.4 MNO Services – Transport

Transport opportunities exist beyond today's backhaul services provided to MNOs. These opportunities are enabled by capacity needed for explosive mobile data growth, and by stringent performance requirements, driven by cell densification and network function virtualization.

2.1.4.1 Cell densification with small cells

Meeting exploding mobile data traffic, within the limits of available spectrum, requires MNOs to rely on increasing spatial efficiency (Bits/Sec/Hz/m2) to improve capacity. This can be achieved by adding small cells that complement macro cells to increase the overall data throughput to consumers. Small cells require backhaul which can be cost effectively provided by service providers.

2.1.4.2 Virtualized radio access network (vRAN)

In conventional Radio Access Network (RAN) architectures, baseband (L1, L2 & L3) processing is done at the macro cell site. In the near future, due to scalability, flexibility and performance

[8] T-Mobile Wholesale Purchase Rates, Wi-Fi Network Cost Bell Labs Consulting estimates, Wi-Fi Price reflects 40% margin on Wi-Fi network cost.

benefits, MNOs will evolve their network to a virtualized radio access network (vRAN) – where key baseband processing functions shift from the cell site onto general purpose processors (GPP) located in a data center. Link capacity between the cell site and the data center will depend on which functions are performed in each location.

- L1 processing performed at the cell site is referred to as Dual-site vRAN, and the link between the cell site and the data center is called a mid-haul link. A conventional IP/Ethernet network can be used for this link.
- L1 processing performed at the data center is referred to as Centralized vRAN and the link is called a front-haul link, used to transmit digital, Common Public Radio Interface (CPRI) waveform samples. Front-haul requires multi-Gbps transport, typically using Wavelength Division Multiplexing (WDM).
- Low-latency (~6 ms for mid-haul and ~300 µs for front-haul) is required to meet tight radio layer timing requirements - essentially mandating the use of an edge-cloud data center.

Service providers will have significant transport opportunities with MNOs to provide small cells backhaul, mid-haul, and front-haul. Additional opportunities may include edge-cloud data centers which could potentially host other network functions.

2.1.5 Small cells as a service

Section 2.1.4.1 addressed the MNO need for cell densification with small cells to meet traffic growth. However, MNOs face hurdles to deploy small cells in volumes:

- Time and cost for site acquisition
- Site/deployment cost
- Power to small cell
- Affordable backhaul at desired locations
- Manage high volume deployments
- Time to market

Fixed line service providers are in an ideal position to cost-effectively address these MNO challenges by leveraging their current assets (backhaul, facilities, pole and strand attachment rights, power, and site and maintenance personnel). Small cells as a service together with Wi-Fi & LTE integration including neutral host small cells on unlicensed spectrum, transport, and edge-cloud data centers present a significant business opportunity to partner with MNOs.

2.2 Options with Licensed Spectrum

2.2.1 Fixed Wireless Broadband

Many countries still do not have widely available broadband services. Even developed countries have areas where it is economically infeasible to roll out fixed infrastructure. Such un-served areas could now be served by fixed wireless access technologies (LTE today and 5G in the future). Service providers who plan to acquire spectrum to provide wireless services or

acquire an MNO as part of a converged access strategy can leverage the spectrum to extend the reach of their network to provide fixed wireless broadband services and tap into an under-served market opportunity.

2.2.2 Full MNO or Limited MNO

There have been a spate of merger and acquisition activities between wireline and wireless providers driven by the need for scale, competitive pressures, or to provide differentiated services such as quad-play and converged services. Given this trend, service providers without a wireless strategy or those who were previously an MVNO are taking the step to become a full MNO by acquiring spectrum. Such operators will have the advantage of deploying the latest technologies without the burden of managing legacy wireless technologies. They additionally have the benefit of deploying a hybrid heterogeneous network (macro + small cells + Wi-Fi) to deliver ultra-broadband wireless services cost-effectively by leveraging their current fixed network assets. Further, these operators can truly drive convergence and differentiate themselves with policy-driven licensed and unlicensed access to provide the best service level and QoE based on access technology, or combination of access technologies.

"Limited MNO" is another variation of the MVNO model where an MVNO acquires licensed spectrum and builds out a small network in targeted "hotspots" to minimize the amount of capacity leased from an MNO.

3 FUTURE NETWORK REQUIREMENTS AND ARCHITECTURE DIMENSIONS

The wireless strategy or strategies chosen by the service provider has a direct bearing on network requirements and architecture. While many of the strategies discussed can be implemented on current networks, there are three key ingredients that drive future wireless networks[9], and the underlying enabling wireline network. These ingredients are:

- Delivery of seemingly infinite capacity - Creating the experience of seemingly limitless wireless control and data plane bandwidth.
- Realization of continuous performance optimization – creating the experience of an always excellent consumer Quality of Experience (QoE).
- Creation of an extremely energy efficient network - substantially reducing energy consumption in mobile devices and the network.

These ingredients in-turn drive a set of network requirements that include: massive scalability, high reliability, ultra-low latency, high bandwidth backhaul, network densification, access diversity, and low energy consumption. Implementing these requirements creates shifts in network architectures. These shifts include:

[9] The Future X Network a Bell Labs Perspective, Weldon, 2015.

- Converged wireless/wireline access - a single platform that provides wireless and wireline access, with the ability to dynamically shift and allocate resources between wireless and wireline based on the need. Building a converged access network can also provide a projected 20% to 40% savings over building discrete wireless and wireline access networks.
- Tunable IP/optical fabric - achieving seemingly infinite capacity and continual performance optimization requires a highly scalable, tunable network fabric built around distributed edge clouds/data centers, Software Defined Network (SDN)-based control, and multi-layer IP/optical optimization.
- Edge clouds and data centers - containing various functions located much closer to the network edge, enabling lower latency, and improved resiliency.
- A network operations system - that exposes tunable network fabric and optimizes the federation of control across multiple domains, and provides flexibility for automation enabling near real-time scaling based on capacity demands.
- Seamless systemic security - using traditional incident and breach prevention security techniques but also utilizing security analytics for enhanced incident discovery, coupled with autonomics for automated incident response.

The roadmap for evolving service provider networks is based on a combination of the wireless strategy (or strategies), the underlying wireline network strategy, the current network, future network requirements and various architecture dimensions. Service providers need to plan their future network to ensure no stranded investments are made.

4 CONCLUSION

In this paper we have identified several possible wireless strategies, key ingredients of future wireless networks that drive a set of network requirements, and resulting architecture dimensions. As previously mentioned, determination of which strategy or combination of strategies and the impact on the network that are most applicable to a service provider, requires a detailed analysis comprised of a blend of scenario planning, market analysis, business modeling and network modeling.

The authors of this whitepaper are members of Bell Labs Consulting (a division of Nokia). Bell Labs Consulting is the leading trusted advisor to enterprises and operators around the world for solving complex network and technology evolution challenges. With the anticipated explosive growth of connected wireless devices and video traffic in the next few years, all service providers and businesses with carrier grade networks will need to re-think how they build, deploy, operate and leverage their network to not only remain relevant, but to thrive. We understand how the network and technology correlates to the economics of the business and the opportunities ahead. Our specialty is to help our customers make and implement the right business decisions where the economics and performance tradeoffs are not well understood

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Acronyms

3GPP – 3rd Generation Public Partnership

ANDSF – Access Network Discovery and Selection Function

AP – Access Point

CA – Carrier Aggregation

CPRI – Common Public Radio Interface

DL – Downlink

EPC – Evolved Packet Core

EPC – Evolved Packet Core

GPP – General Purpose Processor

IoT – Internet of Things

LAA – Licensed Assisted Access

LBT – Listen-Before Talk

LTE – Long Term Evolution

LTE-A – Long Term Evolution Advanced

LTE-U – Long Term Evolution Unlicensed

LWA - LTE-WLAN Aggregation

LWIP – LTE-WLAN Radio Level Integration with IPsec Tunnel

MSO – Multiple Systems Operator

MVNE – Mobile Virtual Network Enabler

MVNO – Mobile Virtual Network Operator

RAN – Radio Access Network

SIM – Subscriber Identity module

U.S. – United States

UL – Uplink

vRAN – Virtual Radio Access Network

WDM – Wave Division Multiplexing