White Paper

Value of Dark Wi-Fi: Financial Impact of a Wi-Fi Offload Market Solution

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Executive Summary

As demand for mobile data capacity grows unabated, mobile network operators are implementing new strategies to keep up with the demand as economically as possible. Many are rolling out Long Term Evolution (LTE) services and using small cells for additional LTE capacity in areas where demand grows beyond the original coverage network. LTE helps lower the marginal cost of new capacity; however, the higher speeds in the not-yet-saturated LTE cell sectors have contributed to increasing demand.

Wi-Fi is already providing significant relief from the relentless growth of mobile data demand. About half of the data to mobile devices is delivered by Wi-Fi, mostly at subscribers' homes and workplaces. Many mobile operators have included Wi-Fi in their plans to build new capacity. Wi-Fi radio access solutions are less costly, and there is no need to buy spectrum. However, the cost of backhaul for many more locations limits the role of carrier-owned Wi-Fi.

A third alternative has emerged, and it has interesting characteristics and cost dynamics. This alternative is the possibility of utilizing the already existing broadband delivery networks and Wi-Fi access points and hotspots to provide mobile data capacity on an as-needed basis. In all areas of high mobile data demand, there are hundreds of Wi-Fi gateways in the footprint of each cellular sector. The signals of these access points reach well beyond the homes and businesses of their subscribers. These signals can readily be seen by opening any device's Wi-Fi settings, which typically show more than 10 networks in any urban area. Together these Wi-Fi gateways represent an enormous source of wireless data capacity, hundreds of times more than all cellular data networks combined.

The number of Wi-Fi access points controlled by Internet service providers (ISPs) and cable multiple system operators (MSOs) is growing rapidly. Most major cable operators and ISPs have started deploying Wi-Fi hotspots in public areas throughout large metropolitan areas. Additionally, many are turning existing subscriber gateways into neighborhood "homespots" by installing firmware updates to start transmitting public Wi-Fi signals that can be accessed by fellow subscribers.

Initially intended for use only by their own subscribers, these millions of Wi-Fi hotspots now represent a vast network that could be used to serve mobile devices. Only a small fraction of the capacity of these broadband/Wi-Fi connections is being used today. This is because every connection is capable of high speed, but is only occasionally used by its subscriber. This large and growing resource – which wireless industry analysts have called "Dark Wi-Fi" – holds the potential to transform the mobile data service in the same way that the unused capacity of dark fiber has transformed the Internet and is still fueling its growth and new services.

The simultaneous need for lower cost mobile data and the existence of unused broadband Wi-Fi capacity, both exactly in the same areas have given rise to a new solution. BandwidthX has quietly launched its electronic marketplace for Wi-Fi offload during the first half of 2013. It offers a means for mobile carriers to buy Wi-Fi capacity only when and where they need it and only in the amount necessary to handle demand exceeding their own cellular capacity. On the sell side of the market are companies that have Wi-Fi access points and "Dark Wi-Fi" in their control. Both sides can define their needs, values and prices for Wi-Fi based on location, cellular sector, time of day and other parameters. When these align, BandwidthX automatically moves data connections of just the right number of devices to available Wi-Fi access points and then handles accounting for the capacity that was used. The signal quality and speed of each Wi-Fi connection is monitored and controlled to meet strict criteria for the connection to be used.

To evaluate the value of this new alternative, some basic questions need to be answered:

- How does the cost of meeting data demand growth change when peak capacity for the busiest cell sectors, during the peak times of the day, can be bought on tap from the Wi-Fi offload marketplace?
- What is the best mix of building cellular base load capacity and buying the peak need from the Wi-Fi offload marketplace? How does the optimum depend on the prices paid?
- What are fair and reasonable prices for on-demand Wi-Fi capacity so that both the sellers and the buyers will benefit and will want to participate?
- How significant is the financial impact of using "Dark Wi-Fi" for the participating companies and for the mobile and ISP industries?

In order to get reliable and quantitative answers to these questions, *Heavy Reading* teamed up with Wireless 20/20. Using the well-known Wireless 20/20 Wireless Return on Investment (WiROI) analysis and modeling tool, they calculated the cost of adding capacity to a just completed LTE coverage network in a major market using three alternative strategies: (1) small cells only; (2) carrier-built Wi-Fi with small cells; and (3) small cells complemented by Wi-Fi capacity bought on demand.

The results of the detailed analysis show that adding on-demand Wi-Fi to the mix achieves significant savings at all reasonable price levels of Wi-Fi.

The analysis shows that the total cost of ownership (TCO) with Wi-Fi from the marketplace is 26 percent lower than when only using small cells. In this scenario, the assumed average Wi-Fi price starts at $5 per GB, and the MNO will cover half of the growth by adding small cells and will buy the rest of the needed capacity during peak hours from the marketplace. In comparison, building carrier-owned Wi-Fi to supplement small cells achieves only 5 percent savings in TCO.

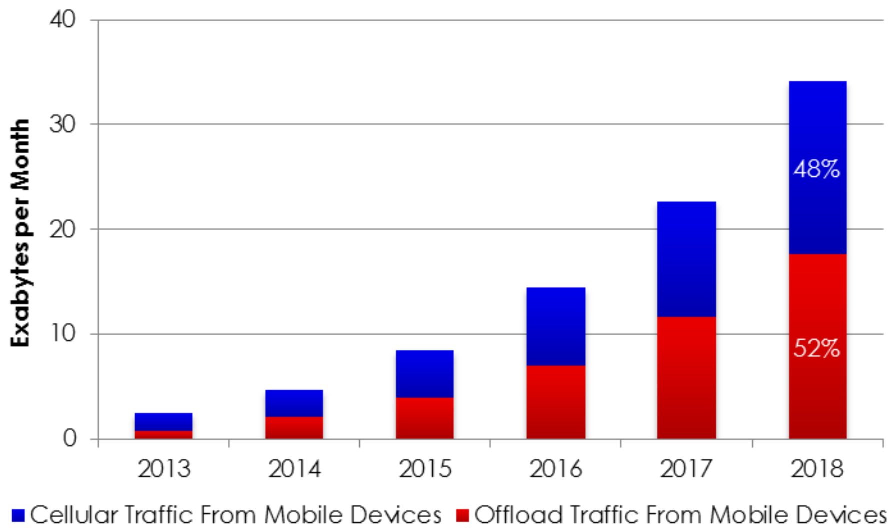
Calculating the optimum MNO strategies for different Wi-Fi pricing reveals two interesting results: (1) to be fair, pricing needs to be granular and dynamic and must depend on conditions in each cell sector; and (2) the average price level influences the optimum mix of Wi-Fi. Increasing price reduces the savings to the MNO and reduces the volume of offload. Lowering price drives the optimum Wi-Fi use up and increases MNO savings and total GBs sold. The model shows that it is possible to find a fair and attractive price for both the buyer and seller in each market situation, but a dynamic pricing mechanism is necessary to do so.

The total impact of harnessing "Dark Wi-Fi" can be very significant. The financial model shows that, in addition to the 26 percent of savings to the MNO, the solution provides 24 percent of the same TCO amount as new revenues to the ISPs that sell the Wi-Fi capacity. In just one metro market for one MNO, both the savings to the MNO over 10 years and the revenue to the ISP are each almost $200 million. In both cases this amount is a direct improvement in profits. The MNO savings, obviously, will directly improve the bottom line and the ISP the revenue comes from selling unused capacity that has a near-zero marginal cost and therefore the revenue directly improves the bottom line.

Mobile Data Traffic Growth Alleviated by Wi-Fi

Mobile broadband demand is at an all-time high and continues to grow. Global mobile data traffic nearly doubled from 820 petabytes per month at the end of 2012 to reach 1.5 exabytes per month at the end of 2013. **Figure 1** presents the latest results of the Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast, which projects a nearly 11-fold increase in mobile data traffic globally from 2013 to 2018. Mobile data consumption per device is expected to grow at a 25 percent compound annual growth rate (CAGR) over the next six years from 600 MB per month to 2.2 GB per month. Combining this with the increase in smartphones on the networks drives the hyper growth. Some operators report a doubling of data traffic each of the last five years.

Figure 1: Mobile Data Traffic Offloaded to Wi-Fi Networks Worldwide



Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018

In the Cisco VNI, mobile data "offload" refers to traffic from dual mode devices that support both cell and Wi-Fi connectivity (excluding laptops). Offloading occurs at the user or device level when one switches from a cellular connection to Wi-Fi access. The Cisco VNI forecasts that by 2018, 52 percent of global mobile traffic will be offloaded onto Wi-Fi networks, mainly at the subscribers' homes and workplaces, up from 45 percent in 2013. More mobile data traffic will be offloaded onto Wi-Fi from mobile-connected devices (17.3 exabytes per month) than will remain on mobile networks by 2018 (15.9 exabytes per month). The amount of traffic offloaded from smartphones will be 51 percent by 2018, and the amount of traffic offloaded from tablets will be 69 percent by 2018.

The use of private Wi-Fi networks and public Wi-Fi hotspots will significantly reduce the impact of mobile data traffic growth on the operator cellular networks. In fact, a recent Mobidia white paper indicates that the use of Wi-Fi may already account for nearly 70 percent of all smartphone-originated data traffic on a global basis within the sample base at the beginning of 2012.

This welcomed relief from mobile data offload is expected to grow, but it is held back by certain practical constraints.

- Offload volume will be determined by the percentage of home or office-based mobile Internet use, the percentage of smartphone owners with Wi-Fi Internet access at home and the percentage of users who have the Wi-Fi radio on.
- Mobile data offload outside the home and workplace is constrained by the cumbersome means to access the pool of offload capacity in public, carrier, amenity and other hotspots.
- There is wide variation in the distribution of smartphone traffic across cellular and Wi-Fi networks, based on the level of private and public Wi-Fi hotspot density and the maturity of carrier Wi-Fi strategies across individual operators within each country.

Needed: An Alternative to Upgrading Networks

Even at a 52 percent offload level, Wi-Fi is not slowing down the need for more cellular capacity enough to avert a serious problem. The remaining 48+ percent compound growth rate is requiring ongoing investments in network expansion at the level of more than $30 billion per year in the U.S. according to a recent CTIA report, "The U.S. Wireless Industry: Leading the World in Investment, Value, Innovation, and Competition."

The U.S. leads the world by investing more than $30 billion in its wireless networks, accounting for a quarter of the world's capital investment and six times more per subscriber than its global counterparts: $94 per subscriber versus $16 per subscriber. *Heavy Reading* estimates that interest and depreciation plus actual operating costs of the network expansion will add almost $10 billion to annual costs. With ARPUs flat or trending down in a saturated market, mobile operators are anxiously looking for more cost effective ways to add capacity.

LTE & Small Cells

The operators are highly motivated to migrate heavy data users to LTE and focus their infrastructure spending on LTE networks, given the spectral efficiency of LTE and in view of the greater potential for capacity gain on the LTE technology roadmap. LTE networks are being deployed initially for coverage using licensed "greenfield" spectrum such as the 700MHz and 800MHz digital dividend bands in the U.S. and Europe, respectively.

As traffic growth starts to impact performance and customer experience on these initial coverage networks, some operators are starting to use higher-band spectrum with outdoor and indoor small cells to increase the capacity and density of their LTE networks, especially in urban markets.

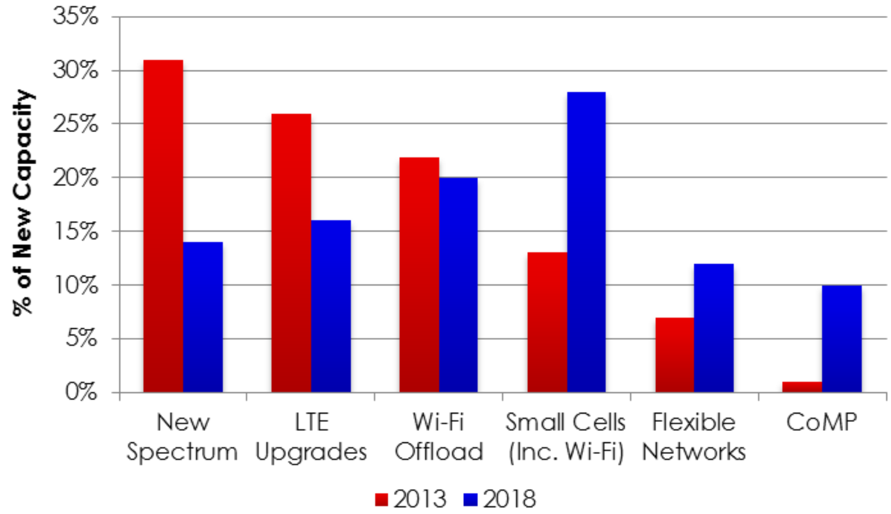
Using LTE and small cells helps control costs. However, there has been an unexpected downside that users have quickly adapted to LTE's faster speeds (when only few users are connected) and better spectral efficiency by increasing their demand for data capacity. The increased use of video and other heavy data services further accelerates demand growth. Even after major deployments of LTE, the operators find themselves in need of an alternative to continuously upgrading their cellular networks.

Carrier Wi-Fi

Many mobile operators have turned to increased use of Wi-Fi outside the home and workplace as a source of relief from the relentless data demand growth. This strategy provides an alternative to cellular network expansion. **Figure 2** summarizes the results of a survey of Tier 1 MNOs worldwide conducted for the Wireless Broadband Alliance, indicating how strategically important Wi-Fi has become in MNOs' plans to address rising data capacity needs.

According to the "Wireless Broadband Alliance Industry Report 2013: Global Trends in Public Wi-Fi," for mobile operators Wi-Fi has moved from being a threat to a significant opportunity to meet the demands of their customers in a high-quality yet cost effective way. **Figure 2** indicates that the MNOs surveyed expect 22 percent of additional wireless data capacity, added during 2013, to come from Wi-Fi offload, and 13 percent from small cells.

Figure 2: Mobile Data Capacity MNOs Expect to Gain From Various Sources



Source: Wireless Broadband Alliance Industry Report 2013: Global Trends in Public Wi-Fi

Figure 3 summarizes the different approaches to carrier Wi-Fi by some of the major mobile operators. Several of the world's largest and most advanced MNOs believe Wi-Fi networks are less costly than a pure small-cell strategy and have already made significant investments in their own Wi-Fi networks to offload fast-growing mobile data traffic, manage network expansion costs and improve their customer experience. Operators that bundle Wi-Fi hotspot access with mobile data packages include AT&T, KDDI, SoftBank Mobile, Telefónica O2, China Mobile, China Telecom and SK Telecom.

Figure 3: Major Broadband ISPs With Wi-Fi Networks Worldwide

REGION/COUNTRY	MNOS WITH WI-FI NETWORKS	MNOS WITHOUT WI-FI NETWORKS
U.S.	AT&T	Verizon Wireless, Sprint
Europe	Telefónica O2	Vodafone, T-Mobile
Japan	KDDI, SoftBank	NTT Docomo
South Korea	SK Telecom	KT, LG U+
China	China Mobile, China Telecom	China Unicom

Source: Heavy Reading

However, the cost of deploying carrier Wi-Fi and arranging new backhaul is still very significant and does not provide a game-changing alternative. Consequently, many of the major mobile operators have not built their own carrier Wi-Fi networks. These include Verizon Wireless, Sprint, Vodafone, NTT DoCoMo, Korea

Telecom and LG U+. Although T-Mobile has not deployed its own carrier Wi-Fi offload network, Deutsche Telekom has launched the largest Wi-Fi network in Germany in partnership with Fon.

KDDI's strategy to seamlessly offload mobile data traffic to a fixed Wi-Fi network is a good example of the proactive use of carrier Wi-Fi. KDDI now operates more than 110,000 cellular base stations and offloads data traffic to nearly 2 million Wi-Fi access points, including "Wi-Fi Home Spots" and "au Wi-Fi Spots." According to teffecient.com, KDDI has reached and exceeded its goal of offloading 50 percent of mobile data to Wi-Fi during busy hours by year end 2013, and plans to install more Wi-Fi access points to keep pace with mobile Internet subscriber and mobile data traffic. This traffic is expected to increase 25 times from 2011-2016, with 20 percent smartphone users generating 80 percent of data traffic.

The majority of the world's largest and most advanced MNOs have yet to integrate Wi-Fi in their peak load capacity plans**.** All of these MNOs have announced major 4G network and small-cell deployment plans, driven by the need to deliver denser, higher-capacity coverage in urban areas. These operators also recognize the need to keep pace with peak demand and traffic growth continuously, but have not yet found a cost effective alternative to building and upgrading their 4G LTE networks. One of the main reasons that mobile carrier Wi-Fi has not proven to be a truly cost-effective solution is the expense of arranging and paying for broadband backhaul for each of the Wi-Fi access points.

While mobile carriers have not embraced large-scale Wi-Fi deployments, there is another group of telecom companies that have found it very profitable and are rapidly expanding their Wi-Fi footprint – fixed line broadband service providers.

Fixed-Line Broadband Wi-Fi Network Operators

Dark Wi-Fi

Figure 4 displays some of the hotspot efforts of broadband ISPs around the world. Fixed-line broadband ISPs already have in place a dense and, in the aggregate, enormously high-capacity broadband backhaul network: the connections to their subscribers' homes and businesses. Many of these connections already terminate at a Wi-Fi gateway, originally intended for the subscribers' private use only.

Moreover, only a few percent of the data capacity in all the existing broadband connections is actually used by the subscribers even when they are subjected to the heaviest use possible by normal broadband subscribers. Most of the time, this resource is not used. This circumstance gave rise to coining a familiar sounding term for this valuable, unused resource. Analysts at Wireless 20/20 first used the term "Dark Wi-Fi" evoking images of the tremendous potential in dark fiber that is still fueling the Internet revolution.

Figure 4: Major Broadband ISPs With Wi-Fi Networks Worldwide

REGION/COUNTRY	BROADBAND ISPS WITH WI-FI NETWORKS	CABLE MSOS WITH WI-FI NETWORKS
U.S.	AT&T	CableWiFi Alliance (Bright House, Comcast, Cox, Cablevision Systems, Time Warner Cable)
Europe	U.K. – BT France – Free, SFR Belgium – Telenet, Belgacom Germany – Deutsche Telekom	Netherlands – Ziggo
Asia	Japan – NTT South Korea – KT China – China Telecom	

Source: Heavy Reading

Hotspots & Homespots

Broadband ISPs all around the world have discovered that offering access to Wi-Fi outside the homes of their residential subscribers bundled in with the broadband subscription is an effective tool for customer retention and acquisition. As a result, many ISPs and cable operators have built large Wi-Fi hotspot networks. These initially consisted of purposefully installed public hotspots placed in locations of high wireless connectivity demand. Recently, these hotspot networks have been complemented and hugely expanded by adding very large numbers of so called "homespots." Any existing subscriber Wi-Fi gateway may serve as a homespot, and it just needs to have a second SSID available.

Currently, most new Wi-Fi gateways deployed around the world already come with at least two and, in many cases, four SSIDs. Each SSID forms an independent wireless LAN on the same device, using the single set of radio and routing hardware. A Madrid-based company called Fon has helped several ISPs turn their legacy gateways into Wi-Fi homespots by upgrading the Wi-Fi gateway firmware over the network. Its ISP customers include BT in the U.K. and SFR in France. The total number of Fon enabled homespots is well over 10 million and projected to be more than 30 million by 2016. Homespots make it possible for the ISP to utilize the unused Wi-Fi capacity for its own purposes while still providing the full service to the subscriber from the same device.

There are several prominent examples of how this kind of Wi-Fi capacity has been used to offer mobile data services by the ISP.

- Free, the second largest broadband ISP in France, is providing broadband access from millions of "FreeWifi" hotspots and homespots.
- Dutch cable service provider Ziggo started a new mobile broadband service by turning the Wi-Fi APs in 1 million subscriber's homes into the world's densest mobile data homespot network.
- Several major Asian broadband/mobile service providers have also enabled millions of homespots on their networks, including KDDI and SoftBank.

The five founding members of the CableWiFi Alliance in the U.S. – Comcast, Cox, Cablevision Systems, Bright House Communications and Time Warner Cable – provide customer access to approximately 500,000 public Wi-Fi hotspots collectively deployed within their respective cable coverage areas. Comcast has increased the number of Xfinity access points from 100,000 at the beginning of 2013 to about a million today and is continuing to grow this network at an accelerated pace. In addition to its public Wi-Fi hotspots, Comcast is the first U.S. MSO to roll out homespots with its "neighborhood hotspot" initiative. It has said it aims to create millions of Wi-Fi access points for use by its customers.

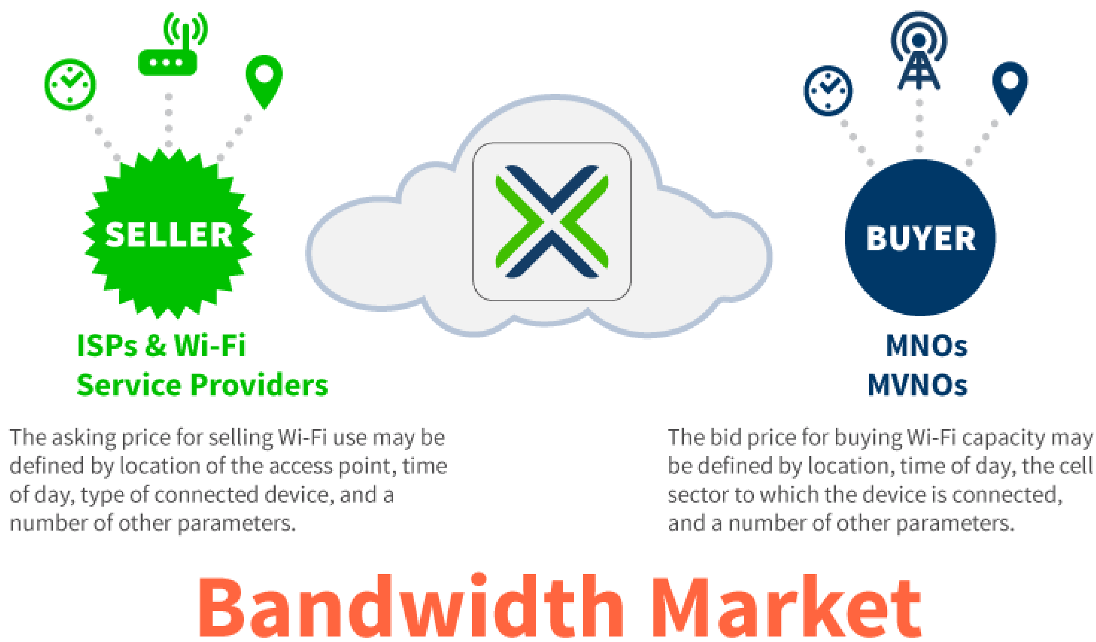
Together, all of these hotspots already constitute a formidable resource of wireless data capacity. Based on announced plans, this resource will continue to grow into a vast and almost ubiquitous resource in urban areas, where the mobile operators are struggling to keep up with demand. This is driven by the relentless growth in mobile data demand and the rapid adding of direct ISP control of the "Dark Wi-Fi" in the very same urban areas. It is very interesting – and in hindsight logical – that a company has emerged that offers a solution to put the "Dark Wi-Fi" to use as a solution to the mobile data demand. BandwidthX has introduced a solution to make unused Wi-Fi from all ISPs available to all mobile operators.

Bandwidth Market: Enabling Offload Commerce

The BandwidthX solution is a cloud-based dynamic marketplace that enables anyone with Wi-Fi capacity to offer it for sale. The capacity can be bought by anyone to benefit any device that is enabled to participate in the marketplace. A small plug-in to any Android app is enough to enable a device to participate.

The marketplace depicted in **Figure 5** knows the Wi-Fi access points and their "listed" asking prices for Wi-Fi capacity. It also knows the mobile devices within the range of each access point and the cell sector to which they are connected. Combining this with the need and value for additional capacity in each cell sector forms the basis of managing connections. Bandwidth Market will automatically make the necessary Wi-Fi connections to precisely meet the need in each sector when the values of the mobile operators and asking prices of ISPs match.

Figure 5: BandwidthX Cloud-Based Dynamic Marketplace



Source: BandwidthX

No Changes Needed to Participate

There are no changes required to existing Wi-Fi access points to participate in Bandwidth Market. Cloud-based servers offer a secure Web portal to enter the pricing of Wi-Fi capacity. In addition to the price, all that is needed is the information about how to authenticate and connect. The servers will provide instructions to participating devices to gain access when appropriate, regardless of whether the access control is based on WPA, username and password, a WISPr gateway or Hotspot 2.0 or other advanced authentication mechanisms. There are no other requirements to take advantage of the opportunity to sell, or to buy Wi-Fi capacity. All the authentication, authorization and accounting (AAA) functions are handled by the cooperation of the plug-in and the cloud-based servers.

Recognizing that all Wi-Fi may not be carrier-grade all the time, BandwidthX has built a series of quality-control features into the plug-in service on the device. For example, the device constantly checks that the signal strength and latency are sufficient for a broadband experience on Wi-Fi and that an Internet connection is available. In addition, a minimum speed check is performed for each connection. Failing any of these criteria results in moving the connection back to cellular or to another Wi-Fi access point.

Once this kind of "on tap, pay only for what you use" access to the enormous Wi-Fi resources of ISPs is made available to mobile operators, the economics of adding mobile data capacity to meet the growing demand could be transformed. As noted above, many leading ISPs around the world have already enabled Wi-Fi access to their practically unused broadband infrastructure for churn reduction. Once the access is enabled, the marginal cost of adding traffic to the unused network (putting the "Dark Wi-Fi" to use) is practically zero. Enabling such access to the rest of the existing broadband networks through firmware upgrades and multiple SSIDs is a reasonable one-time expense. Comparing the value of harnessing the existing Wi-Fi for mobile data use to the cost of enabling access to it leads to the conclusion that enabling the access will spread across most ISP networks.

The remainder of this white paper examines the financial impact to both the ISPs and the MNOs of selling Wi-Fi capacity and buying on-demand Wi-Fi, respectively.

Financial Impact of Using a Wi-Fi Marketplace

With current network expansion practices, MNOs are required to continually invest more capex and opex into their networks to keep up with expanding data demand. If an MNO could procure on-demand capacity from Wi-Fi operators only in select locations and at peak times of the day, it could lower costs and use its resources more efficiently to meet soaring demand.

A Wi-Fi marketplace creates a new tool that allows MNOs to achieve this; however, the key question is how much an MNO should pay for a GB of overcapacity data. Fortunately, a model can be developed to understand the evolving value of offload and its temporal and spatial dependencies as demand grows and a network is in overcapacity. To quantitatively analyze this key question, Wireless 20/20 has expanded its WiROI Business Case model to enable a direct comparison of alternative strategies, explore the optimum balance of Wi-Fi offload at different pricing levels and measure the financial impact of a Wi-Fi marketplace.

WiROI Business Case for BandwidthX's Wi-Fi Marketplace

The WiROI model examines a 10-year business case for a major MNO deploying 4G LTE in a major urban city. New York City is used as the test case. The network covers only the urban areas (789 km^2) and includes approximately 8 million covered people (2.7 million households). The model divides the city into 100 geographic percentiles and ranks them from busiest to least busy areas. In addition, it looks at the hourly distribution of data usage over a typical day.

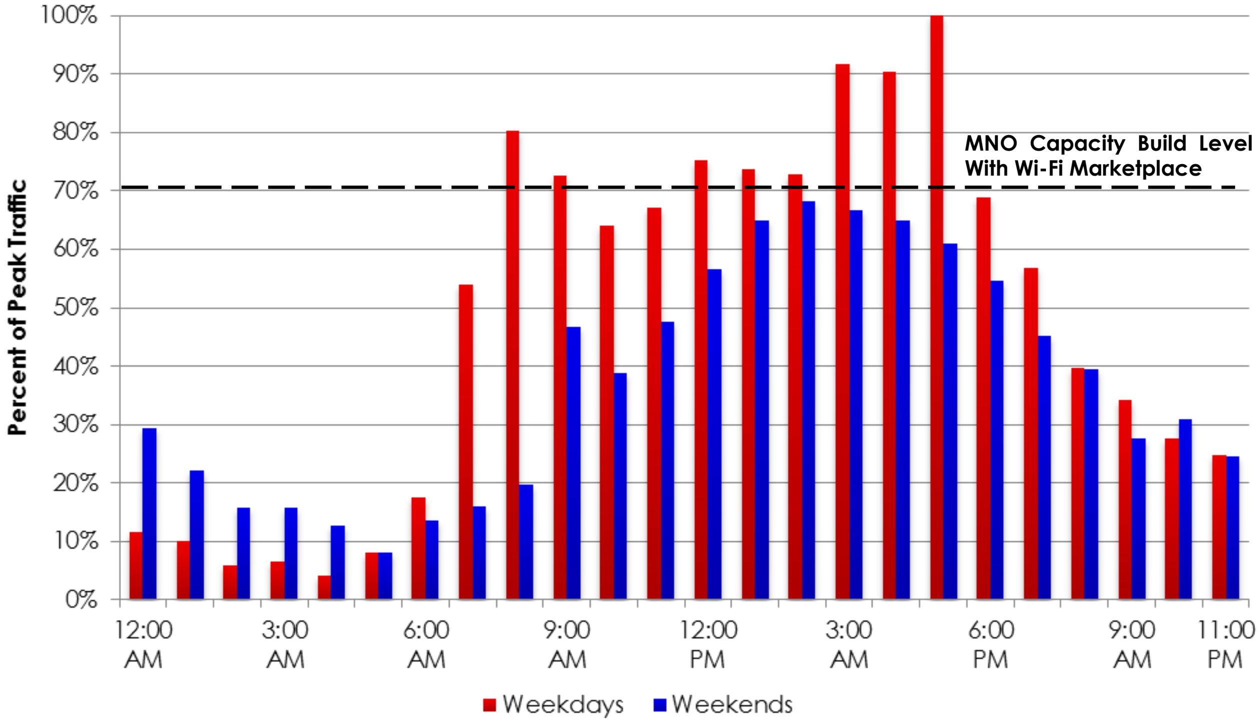
The model assumes that an MNO with a 24 percent market share has an existing 3G network and has begun transitioning users to a newly-deployed LTE coverage network. During the modeling period, the number of LTE subscribers will grow from a few hundred thousand to 2 million. By growing the number of LTE subscribers and the estimated usage per subscriber, the WiROI model can predict:

- Where the network is over capacity
- When the network is over capacity
- How much additional data capacity needs to be supported

By modeling the load on the network based on the geographic traffic distribution and the distribution of traffic over the day, the model can predict which areas of the network will be overcapacity, and at what time of day. At the beginning, the MNO has deployed a coverage network to provide service across the city. As subscribers are added to the network, certain critical areas of the network quickly begin to reach capacity. Across any network, demand is not uniform and certain areas have a greater concentration of traffic. These are the areas where the MNO begins to see congestion. Even in the sectors that require additional capacity, the need is initially only during the busiest hours of the day. **Figure 6** shows a typical hourly variation in the cellular data demand during weekdays and weekends.

Expanding capacity in a typical cell sector requires tens of thousands of dollars in capex and adds hundreds of dollars per month to opex. Since the initial need for additional data capacity in sectors is small, a simple calculation shows that a low utilization of network expansion means a high per GB cost during this time. For this reason, there is an optimum strategy that MNOs can follow for using on-tap Wi-Fi for some portion of the data demand to avoid these monthly expenses.

Figure 6: Typical Hourly Variation in Mobile Data Demand on Weekdays & Weekends



Source: Wireless 20/20

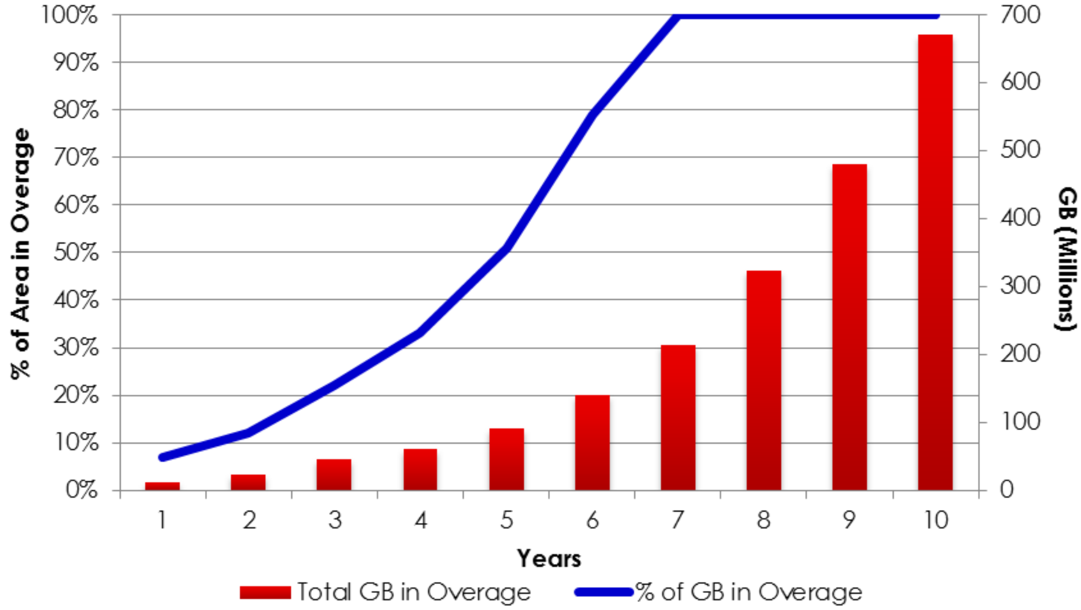
The current practice for building network expansions requires that MNOs build to the requirements of the busiest hour. The opportunity to access Wi-Fi capacity only where and when needed and only in the amount required to meet peak demand brings a new tool to MNO's arsenals. However, to harness this resource, the following questions must be answered:

- What portion of capacity expansion should be avoided using Wi-Fi offload?
- What is a fair and reasonable price for Wi-Fi?
- How significant can the savings from Wi-Fi become?
- How much revenue can an ISP generate selling Wi-Fi in the marketplace?

Network Data Traffic & Expansion Predictions

The annual results of the traffic modeling exercise are depicted in **Figure 7.** As the demand gradually grows, first the busiest areas in the city start needing additional capacity, and in the following years, the area where capacity is needed will continue to expand. In Year 1, with the initial subscribers just beginning to use up the capacity of the network at the busiest hours, the blue shows only the busiest 7 percent of the geographic areas will need additional capacity. By Year 3, the areas of the network that are in need of capacity spreads to 30 percent of the network. About 50 percent of all areas are in need of capacity by Year 5, and by Year 7, all areas in the city need additional capacity.

Figure 7: Model of Network Overage



Source: Wireless 20/20

The total daily tonnage of overage is shown on the bars of **Figure 7**. It begins at about 10 terabytes at the end of Year 1. As more subscribers are added and usage grows, the daily need for incremental capacity grows to over 600 terabytes. To meet this increase in demand, an MNO would need to build ten times the number of capacity cell sites as deployed in the original coverage network if it was to implement a typical network expansion strategy.

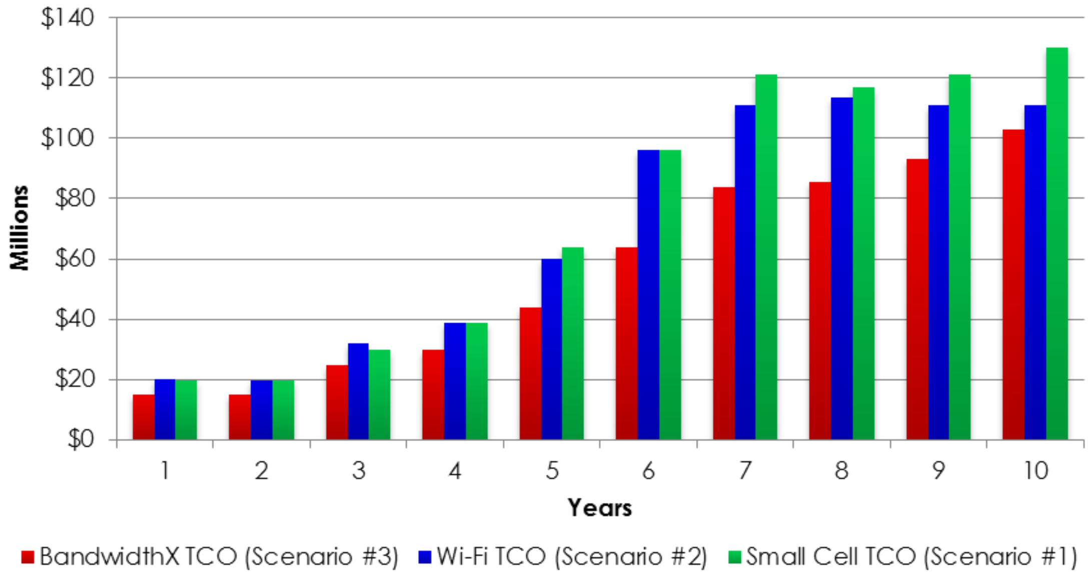
Assuming the carrier implements a small-cell strategy to meet growing demand, the WiROI model calculates the projected cost. The model adds small cells into the network only in the areas that go into overcapacity, and calculates how many additional small cells are needed to account for the required capacity demand growth.

In the example of New York City, the initial coverage network blankets 789 km^2, using about 1,100 macrocell sites. In order to account for all of the traffic growth, the MNO would need to deploy over 13,000 small cells over 10 years. The baseline TCO over 10 years for this would be about $750 million. These results represent the baseline cost for handling the capacity expansion using the most effective and lowest cost cellular technology available today.

The modeling results depicted in **Figure 8** shows an average annual cost level of about $30 million in the first five years, which comes to about $15 per subscriber. Since the national average of annual capex is about $100 per subscriber, these numbers represent the lower boundary of actual costs in the U.S. and are fairly well in line with the global average. Regarding how soon additional capacity is needed, the model seems representative of actual conditions. For example, Verizon CEO recently announced that "around a dozen" cell sites have capacity issues and that it would already upgrade 50 of their 300 LTE network cell sites in

New York area by adding AWS spectrum to boost the capacity at locations where they have had issues.

Figure 8: Annual TCO Comparison



Source: Wireless 20/20

TCO of Small Cells vs. Carrier Wi-Fi & Wi-Fi From the Marketplace

This analysis compares the baseline small cells TCO against building and operating a carrier Wi-Fi network and using a blend of small cell deployment and Wi-Fi capacity from the Wi-Fi marketplace. To do an apples-to-apples comparison of the three alternatives, the model calculates three deployment scenarios:

1. Building small cells to meet the increasing demand. The model accounts for all capex associated with building and deploying the small cells, and the opex for the ongoing operation of the network. This is the base case.
2. Building a carrier-owned Wi-Fi offload network to augment the capacity of the LTE coverage network. The carrier's Wi-Fi network helps to offload some of the overage capacity, but still requires some small cells to be deployed. The TCO is the total cost of both the carrier Wi-Fi network and the small cells that are still deployed.
3. Meeting the capacity demands by buying Wi-Fi capacity on an as-needed basis from the marketplace. The model can adjust how much of the overage demand is built by the operator (from 0 percent to 100 percent) using small cells and assumes that the rest of the capacity is bought from the Wi-Fi marketplace.

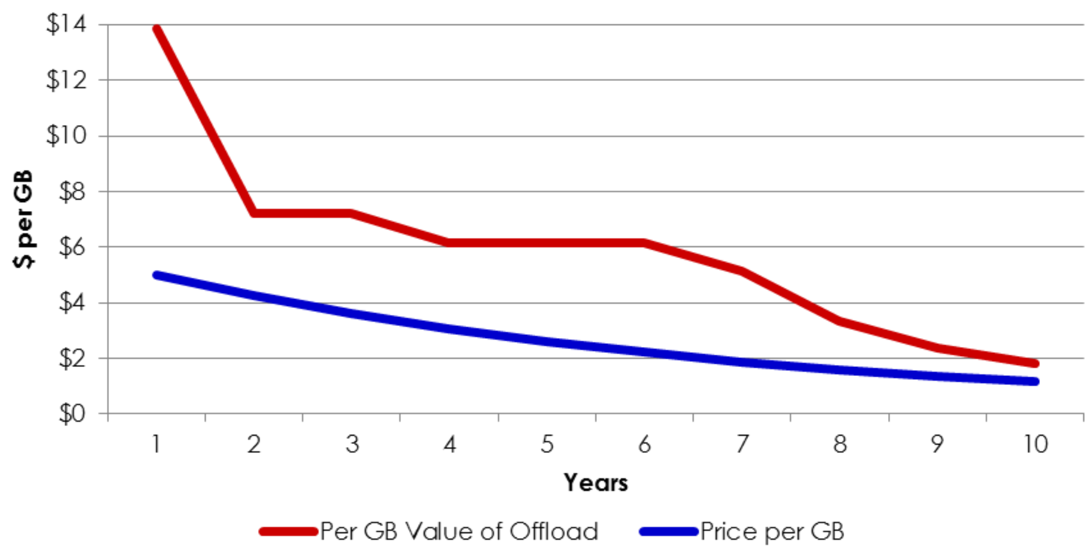
As described in Scenario #2, if an operator deploys its own Wi-Fi access points to supplement the capacity of the small cells, the total cost over the 10 years works out to be just a little bit lower. Similar to the small-cell approach, a carrier Wi-Fi build adds access points only in the areas where the network goes into overload.

The carrier Wi-Fi capacity can be effective when deployed in the heaviest traffic areas. However, the cost of deploying and supporting Wi-Fi APs when the overage traffic spreads across the whole geography will be higher than the cost of deploying small cells. For this scenario, the model uses a combined approach that takes maximum advantage of Wi-Fi where it is possible.

The opportunity for savings by utilizing Wi-Fi capacity purchased from the marketplace depends on the cost of Wi-Fi and the portion of network expansion that is replaced by this Wi-Fi capacity. This is modeled in Scenario #3.

Figure 9 shows the estimated value per GB offload for the MNO and estimated market price per GB paid over the 10-year business case. Using the baseline calculation, the value per GB is calculated by dividing the total cost (minus the portion of the overage the MNO builds) by the total number of overage GBs on a year-by-year basis. This gives a rough estimate of how much an operator might be prepared to pay for Wi-Fi capacity. While this cost estimate varies for each time and area of the network, the typical range is between $2 and $10 per GB. A starting average price for Wi-Fi of $5 per GB across all areas was used in the model. The price was set to decline 15 percent per year as the volume of Wi-Fi purchases grows. Further, it was assumed that the MNO will build 50 percent of the overage capacity need and will buy the peak capacity above that level from the Wi-Fi marketplace.

Figure 9: Estimated Value for MNO & Marketplace Price per GB of Offload

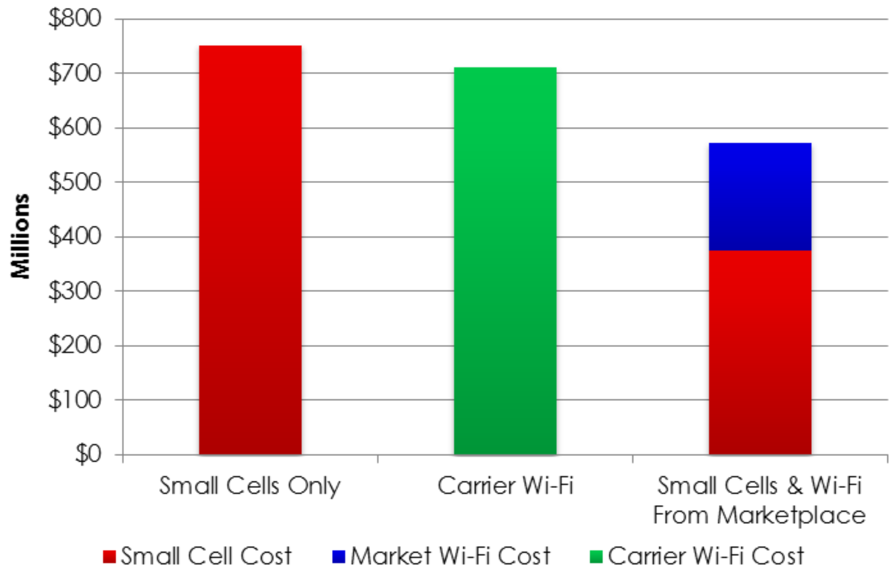


Source: Wireless 20/20

Comparison of Results

With these assumptions, the savings to the MNO in TCO over the 10-year period will be $198 million in the New York market – a savings of about 26 percent. **Figure 10** compares the TCO of all three alternatives and shows the cost of Wi-Fi purchases ($178 million) and of building small cells ($375 million) in this scenario. The detailed annual comparison of the three alternatives is shown in **Figure 8**.

Figure 10: TCO Comparison



Source: Wireless 20/20

A breakdown of the annual expenditures for building small cells and buying peak capacity from the Wi-Fi marketplace for the model example is shown in the right bar of **Figure 10**. The split in the costs depends on the strategy followed by the operator. An operator could choose to build more of the overage capacity needs and buy less from the marketplace, but would likely pay a higher price. Conversely, the operator could buy more volume at a lower price, and would save significantly on the investment required in small cells for capacity expansion.

Optimizing TCO of Meeting Data Demand

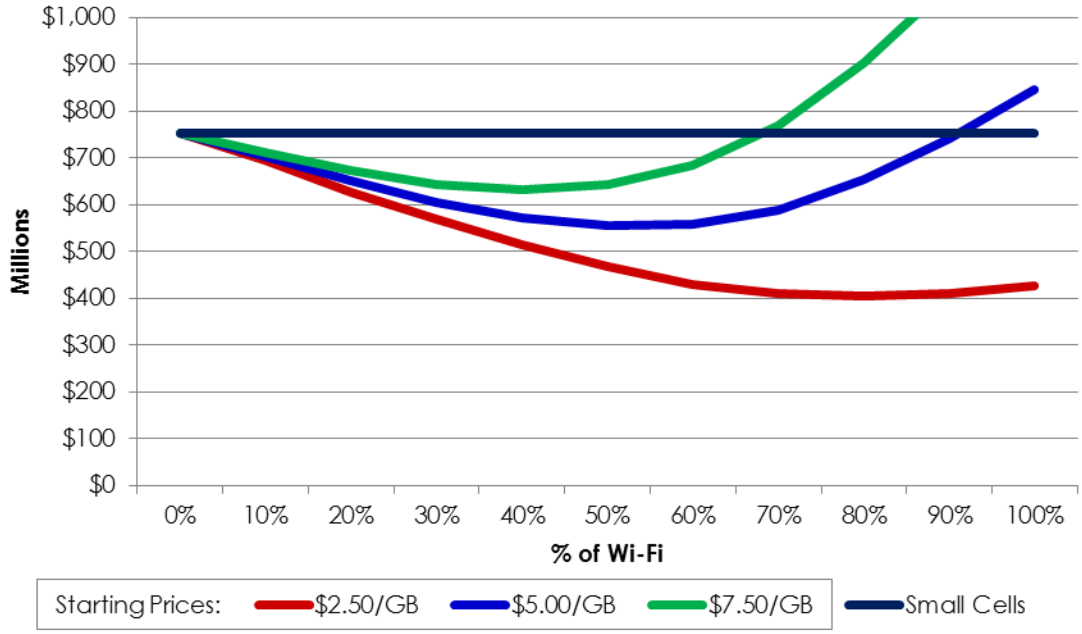
The WiROI model can vary the amount of the overage capacity built by the MNO, as well as the cost of Wi-Fi bought from the marketplace. An analysis was performed that shows how this new network planning paradigm and variation in these two parameters affects the MNO's cost.

Depending on what price the MNO pays from the marketplace, there is an optimized build plan for the MNO, which minimizes the TCO for supporting the capacity growth in the network. If the MNO builds a higher percentage of the over capacity, then it buys less capacity from the marketplace. But since it would be buying only the peak capacity required, the value of these bits would be much higher. Conversely, if the MNO could buy capacity at a lower price, then they would build fewer small cells.

The results in **Figure 11** show this minimum TCO for three pricing levels:

- At $2.50/GB in Year 1, MNO should build 25 percent of peak overcapacity
- At $5.00/GB in Year 1, MNO should build 50 percent of peak overcapacity
- At $7.50/GB in Year 1, MNO should build 65 percent of peak overcapacity

Figure 11: Overage Network TCO



Source: Wireless 20/20

The savings to the MNO in these scenarios range from $125 million to $350 million.

The capability to buy on-demand capacity from the Wi-Fi marketplace gives MNOs a powerful new tool for planning network capacity growth. Similarly, it gives sellers of Wi-Fi capacity a great way to maximize the monetization of their assets. Sellers can decide to pursue either a high-volume/low-price strategy to maximize their revenue, or a low-volume/high-price strategy to maximize their margins.

In the case depicted in **Figure 10**, the seller would see $178 million in revenue from one operator in this one market over the 10 years of the test case. This represents about 24 percent of the TCO of the mobile network operator in this market.

The overall impact of buying Wi-Fi capacity from the Wi-Fi offload market in this scenario is 26 percent savings of the TCO to the MNO plus 24 percent revenue of the same TCO as new revenue to the ISPs providing the Wi-Fi capacity. Considering today's cost levels and the growing need for additional network expansion to meet the data demand, the potential impact of harnessing "Dark Wi-Fi" is billions of dollars for both the MNOs and ISPs. In both cases, this effect is felt directly on the bottom line. For MNOs it is direct cost savings and for the ISPs it is revenue from selling existing capacity that is unused today.

As demand continues to grow, "Dark Wi-Fi" will likely become an essential part of the solution in countries with reasonably high-penetration broadband networks.

Conclusions

The opportunity to precisely buy on-demand Wi-Fi offload capacity to cover peak demand only at certain areas and times of day provides a very interesting new alternative for MNOs to optimize their planning and approach to meeting the growing mobile data demand. This new paradigm will afford MNOs the ability to not continually expand capacity to meet their busiest hours, but instead, pursue tailored strategies to support their economic objectives.

Detailed analysis using the Wireless 20/20 WiROI financial modeling tool reveals that at all reasonable Wi-Fi price levels MNOs can realize significant savings by adding purchases of on-demand Wi-Fi capacity to cover peak demand to their mix of tools.

For example, at prices starting at $5 per GB a mobile operator can save 26 percent in TCO by building for less than the peak demand. At this price level a mobile operator in the New York market would save about $200 million in TCO over 10 years and, at the same time, the Wi-Fi service provider would earn about $180 million by selling their unused capacity. Consequently, utilizing "Dark Wi-Fi" is making both the buyer and seller more profitable.

To achieve fair and attractive pricing in each cell sector, the prices must be dynamic and depend on the situation in each sector. The average price levels affect the optimum strategy and total volume of Wi-Fi use, but it is possible to find attractive pricing for both the seller and the buyer in each situation.

The other findings of this analysis include:

- Using the Wi-Fi marketplace capacity is most valuable in peak times
- Access to Wi-Fi capacity is most valuable on a per-GB basis when cell sectors first go into overage, not in heaviest traffic areas
- Buying Wi-Fi capacity from the marketplace creates a new tool for optimizing network planning for mobile operators

The use case for every mobile operator's deployments may be slightly different. Each case can be analyzed separately to determine the exact parameters for the value of offloaded data and the optimum strategy of building and buying capacity. The Wi-Fi offload marketplace provides a flexible platform for implementing the optimized approach.

All mobile operators will be faced with the challenge of supporting the continuing growth of mobile data demand. Natural use of Wi-Fi at subscribers' homes and workplaces takes on a portion of the growth, but the remaining cellular demand is still a major cost concern. Advances in LTE and small cells have helped, but higher speeds are also fueling the demand.

A new and abundant resource has emerged that can be added to the set of tools for operators: making available unused Wi-Fi capacity in hotspots and homespots. This unused "Dark Wi-Fi," which can be bought and sold on demand through the cloud-based Wi-Fi offload marketplace, holds the promise to provide major savings to MNOs and, at the same time, provide a way for ISPs and MSOs to directly profit from the mobile data demand without requiring incremental investment or changes in their broadband and Wi-Fi networks.