A Total Cost of Ownership Analysis of the Meru Networks Virtual Cell Wireless LAN Architecture

Network Strategy Partners, LLC

MANAGEMENT CONSULTANTS TO THE NETWORKING INDUSTRY

www.nspllc.com

February, 2008

Network Strategy Partners, LLC (NSP) — Management Consultants to the networking industry — helps service providers, enterprises, and equipment vendors around the globe make strategic decisions, mitigate risk and affect change through custom consulting engagements. NSP's consulting includes business case and ROI analysis, go-to-market strategies, development of new service offers, pricing and bundling as well as infrastructure consulting. NSP's consultants are respected thought-leaders in the networking industry and influence its direction though confidential engagements for industry leaders and through public appearances, whitepapers, and trade magazine articles. Contact NSP at www.nspllc.com.

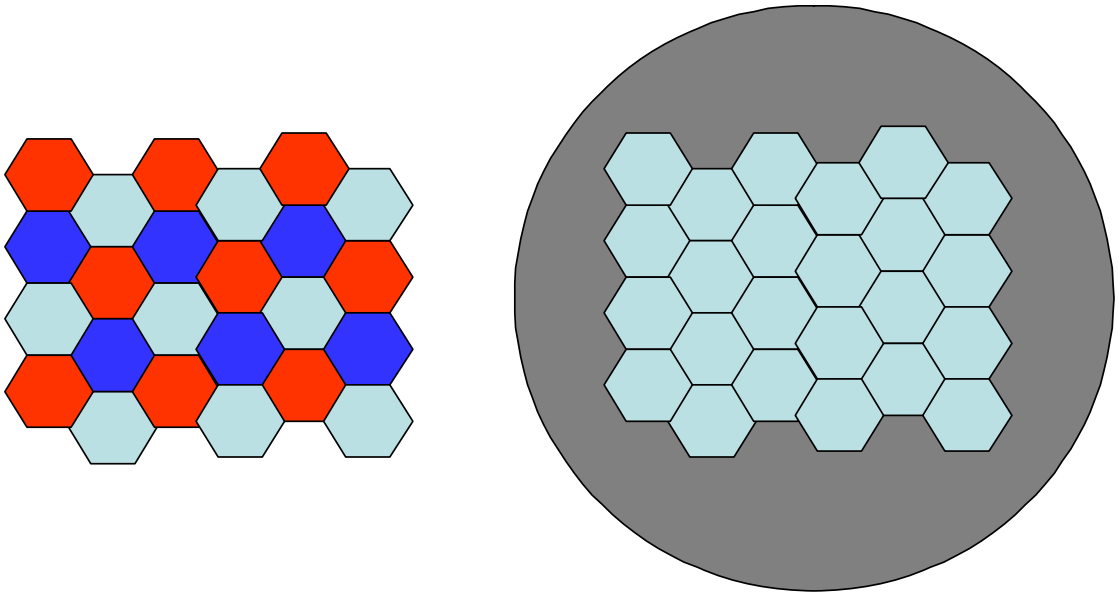
TABLE OF CONTENTS

Executive Summary

Wireless LAN technology has grown rapidly and is now a standard part of network infrastructure in most enterprises. As the market has grown, WiFi technology has evolved and matured from single Access Point (AP) systems to networks with multiple APs managed by a central controllers. These centrally managed AP networks are more scalable and manageable then first generation networks consisting of standalone APs and have been widely deployed in enterprise wireless networks. However, a fundamental problem in any cellular wireless network is the management and allocation of frequencies and power control between cell sites. Frequencies must be allocated so that network capacity is maximized, however frequencies must be separated and power must be controlled between cells to avoid co-channel interference. Many of the multiple AP wireless networks today use this approach. We will call this the Micro Cell Architecture.

Meru networks has advanced the state of the art defining a new generation of WiFi networking. Meru uses an innovative approach, creating a large network of multiple APs, controlled by a central controller, that appears like a single AP to a WiFi client. It uses advanced techniques within the standard 802.11 protocol to schedule client access, manage contention among WiFi clients and allow all APs to operate at maximum power levels, thus increasing overall network performance and minimizing the cost of installing and managing the network. This is called the Virtual Cell Architecture (because all cells appear to the client to be a single AP).

The Micro Cell Architecture and the Virtual Cell Architecture are compared in Figure 1. In the Micro Cell network multiple frequencies need to be planned, allocated, and managed between cells creating a complex RF environment. In the Virtual Cell network a single frequency is used across all cell sites and access is centrally managed by the controller. The RF complexity of the network is therefore eliminated by the smart Meru algorithms in the central controller.



Micro Cell Architecture requires frequency spacing

Virtual Cell Architecture uses a single frequency to cover an area

Figure 1
Comparison of Micro Cell and Virtual Cell

The Virtual Cell Architecture also implements QoS, thus allowing voice and data to run on the wireless LAN with high reliability and performance. For the first time enterprises can move to a completely wireless network infrastructure—eliminating expensive wiring and moves, adds, and changes. By allowing enterprises to build reliable, high performance wireless networks, it is now possible to eliminate wired LAN and telephone expenses in new buildings.

The TCO analysis presented in this paper shows that the cost of building a Meru wireless 802.11n network is $0.57 per square foot as compared to a cost of $2.64 per square foot for installing cables and LAN network infrastructure. In 250,000 square feet of office space, this results in a savings of $517,192 or $2.07 per square foot. The high level break down of the installation and equipment costs for both the wired and wireless networks is depicted in Figure 2.

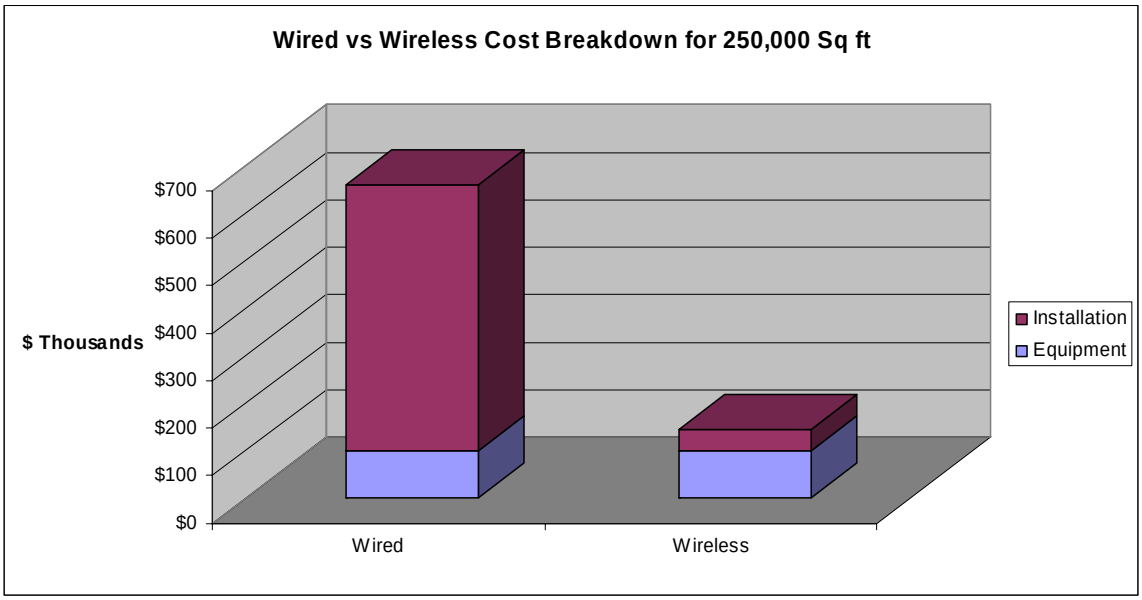


Figure 2

Our analysis also shows that the Meru Virtual Cell Architecture is more cost effective than the Micro Cell approach. In this analysis we compare the Meru equipment to Micro Cell equipment from a leading networking vendor. The sources of the cost savings are:

- The Meru network design has 29% less access points than the Micro Cell design
- The Virtual Cell network does not require extensive site survey and RF engineering, therefore, engineering and installation costs for the wireless network are reduced

Our findings are:

- A Micro Cell 802.11a/b/g solution is 58% more expensive than the Meru solution
- A Micro Cell 802.11n solution is 45% more expensive than the Meru solution

At a high level the break down of the installation and equipment costs for both the Micro Cell and Meru Virtual Cell 802.11a/b/g networks is depicted in Figure 3.

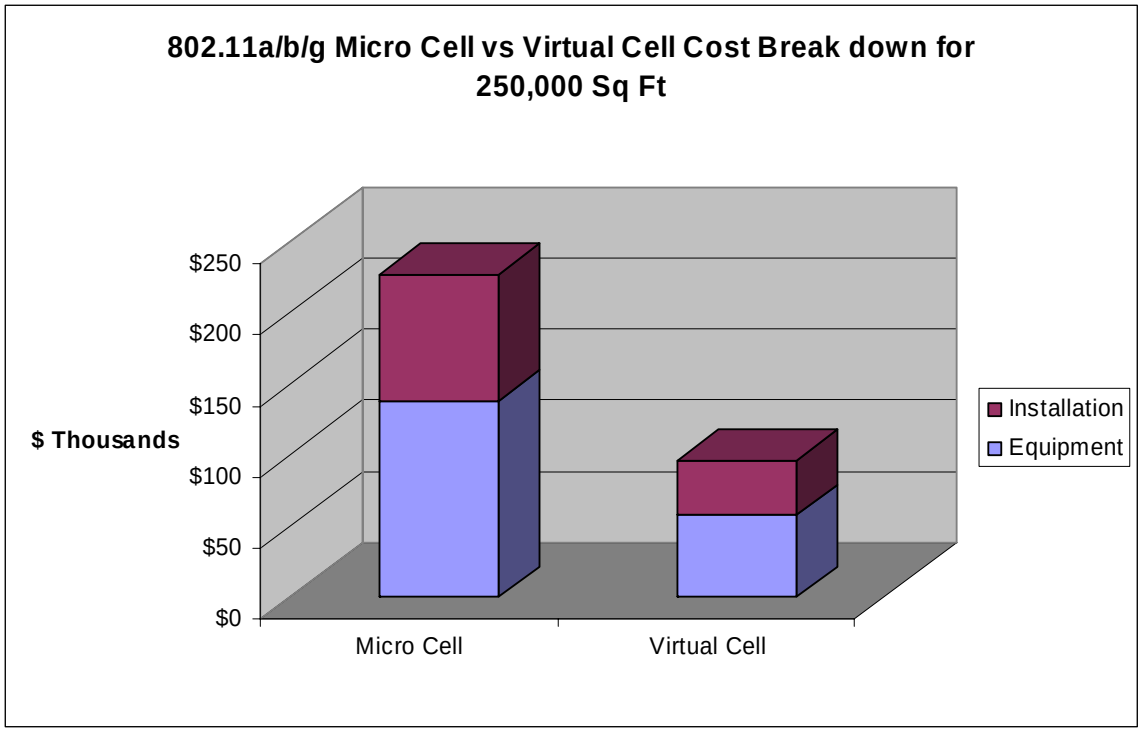


Figure 3
Cost break down for the 802.11a/b/g/ networks

The following sections of this paper present an overview of the Meru value proposition explaining the reasoning behind the TCO benefits stated above. Then a TCO model is presented along with the associated modeling assumptions. It is used to compare the Meru Networks' Virtual Cell Architecture with three architectural alternatives:

- Wired LAN and telecommunications infrastructure
- Micro Cell 802.11a/b/g
- Micro Cell 802.11n

Detailed results are presented and the sources of the Virtual Cell Architecture's TCO advantage for each alternative are described.

Meru Value Proposition

Meru's Air Traffic Control wireless LAN is a unique architecture (Virtual Cell) that optimizes wireless network capacity, traffic control, and QoS, while simplifying network operations and planning activities. These benefits are achieved by the Virtual Cell Architecture which makes all the APs in the network appear as a single AP. The Meru controller manages client-AP associations, schedules traffic, guarantees QoS for voice applications, and maximizes RF power and network capacity. There are multiple benefits to the Virtual Cell Architecture, including:

- APs transmit at maximum power levels (100mWatts)
- Higher power translates to higher SNR and higher average data rates

- Higher power also means that fewer APs need to be deployed in a Virtual Cell network than in a Micro Cell network
- Central control minimizes co-channel interference
- Bi-directional QoS is provided for voice traffic (from AP to Client and Client to AP)
- No Hand-offs are required between APs
- The network can optimize load balancing by controlling Client-AP associations and scheduling traffic to optimize distribution of the load

As a result of these benefits it is possible to run all voice and data through a Meru wireless network eliminating the need for wired LAN and telephone infrastructure. The next section analyzes the business case for a completely wireless infrastructure.

The Business Case for Going All Wireless

The Meru Virtual Cell Architecture provides a high performance, scalable, wireless network that is capable of replacing the wired LAN and telecommunications infrastructure. It is possible to use the wireless network for all voice and data communications because the QoS features in the Meru network provide reliable, high quality voice communications. This section of the paper uses an ROI model to analyze the business case for an all wireless office network.

The following assumptions are used to drive the ROI analysis:

- The cost comparison is carried out for a new facility with no existing wiring
- The facility is a standard office with cubicles and conference rooms
- All cubicles are 8 X 8 feet (64 Square Feet)
- 70% of the office space is taken up by cubicles
- The office space is 250,000 square feet which holds 2,735 cubicles
- For the wireless network alternative it is assumed that all voice runs on WiFi VoIP phones
- For the wired network alternative voice and data lines are run to each cubicle
- For the wired network, standard digital phones and a PBX are used for voice communications—the costs of the phone system are not considered in this analysis
- It assumed that there are 69 printers and other devices on the network in addition to phones and computers in cubicles
- Power-over-Ethernet (PoE) is required for all APs
- The diameter of a Meru cell is 70 feet
- A Meru 802.11n network is used for wireless access

The assumptions for costs are specified in Table 1 below:

Item	Cost
Edge Switch Cost per port	$35
PoE Cost per port	$35
Wiring Cost per Drop (Voice and Data)	$200
Wiring and installation cost per AP	$250

Table 1
Cost Assumptions

	Meru Wireless Network	Wired Network
Network Elements		
Number of Wired LAN Port	0	2804
Number of AP's	83	0
Hardware and Software Costs		
Ethernet Switches	$ -	$98,140
Access Points	$ 69,430	$ -
PoE ports	$ 2,905	$ -
WLAN Controllers	$ 25,543	$ -
Total Hardware Cost	**$ 97,878**	**$ 98,140**
Operations Expenses		
RF Design and Planning	$ 6,500	$ -
Installation/Cable	$ 20,750	$ 547,000
Configuration/Testing	$ 2,860	$ -
Maintenance Contract	$ 14,682	$ 14,721
Total Services and Support Cost	**$ 44,792**	**$ 561,721**
Total Expenses		
Total Cost of Hardware and Operations	$ 142,670	$ 659,861
Total Cost per Square Foot Building Space	$ 0.57	$ 2.64
Total Cost Savings	**$ 517,192**	
Cost Savings per SQ FT	**$ 2.07**	
Ratio of Wired to Meru Wireless TCO	**463%**	

Table 2
Cost of Comparison of a Meru wireless network with a wired network in 250,000 square feet of office space

The results of this analysis is presented in Table 2. Wireless equipment costs are lower then wired equipment costs, however, the major component of savings is due to the elimination of wiring expenses. At a cost of $200 per drop, these costs are significant in large facilities. Figure 4 presents a sensitivity analysis comparing the costs of a wired network with a wireless network in different size facilities. This analysis shows that there are benefits to implementing wireless in smaller areas as well as large facilities.

When corporate tenants move into new facilities, there is usually construction, installation of new cubicles, and complete wiring for voice and data to all cubicles. For many medium and large companies such moves are fairly common and result in extra expenses to support business growth. By providing a reliable, high performance wireless network solution, Meru can help companies mitigate the expenses associated with building wiring.

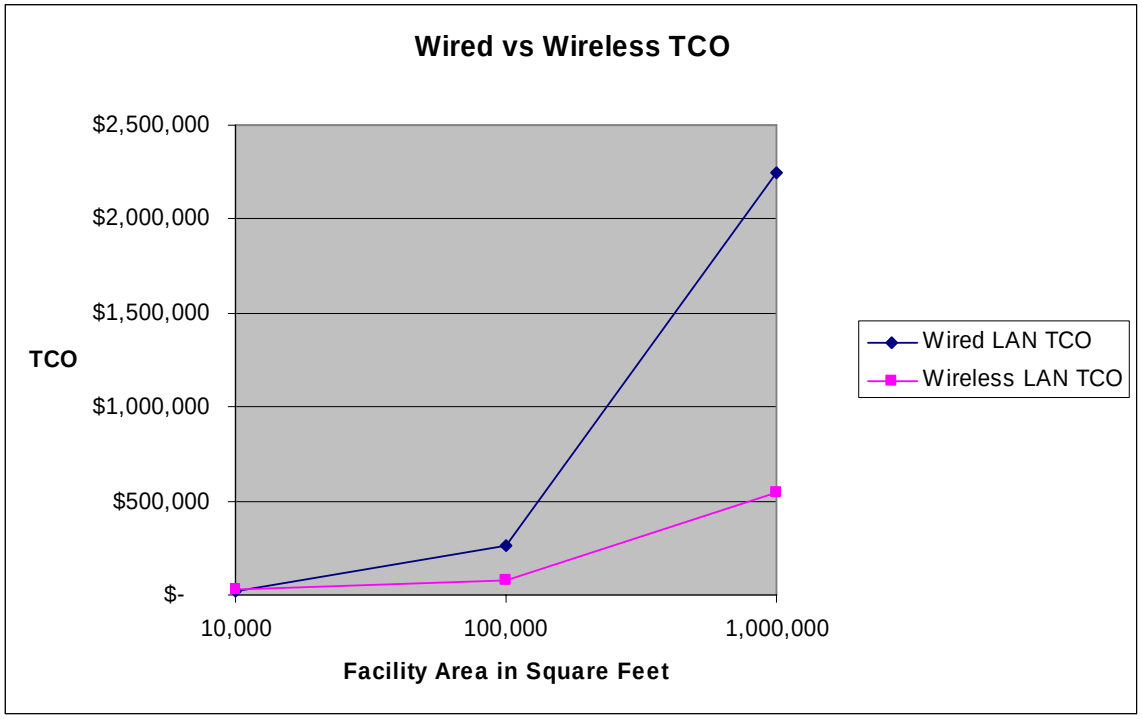


Figure 4
Comparison of Wired vs Wireless expenses for Different Facility Areas

A TCO Comparison of the Meru Virtual Cell to the Micro Cell Architecture

There are many technical reasons why Meru's Virtual Cell network is superior to Micro Cell networks. However, in addition to Meru's technical advantages, it is also a more cost effective solution than the Micro Cell wireless network. There are two primary reasons why this is so:

1. The Meru Virtual Cell network requires approximately 29% less APs than the Micocell Network.
2. Complex site surveys and RF engineering efforts are less complex and therefore less expensive because all Meru APs operate at full power—sharing the same virtual cell channel.

The first question is *why does Meru require less APs than the Micro Cell network*? This is simply a result of Meru APs transmitting at the maximum power level of 100mWatts as compared to a Micro Cell AP which typically transmits at lower power levels of

50mWatts or less. Micro Cells transmit at lower power to increase network capacity by adding more cells—low power is required to minimize co-channel interference. This is not necessary in the Virtual Cell network because all traffic is centrally scheduled and co-channel interference is minimized by the central controller. If we assume that the power of a Micro Cell AP is half that of the Meru AP, then the ratio of the Micro Cell radius to the Meru Cell radius is 0.84. This means that in a given area covered by a wireless network, the Meru Virtual Cell network requires approximately 29% less APs than the Micro Cell network.

The result stated above can be derived from first principles as follows:

S_1 = Meru Signal
S_2 = Micro Cell Signal
P_1 = Meru Power
P_2 = Micro Cell Power
K = RF propagation constant
r_1 = Meru cell radius
r_2 = Micro cell radius

The propagation of an RF signal indoors is expressed by:

$$S = KP/r^4$$

The Meru AP can transmit at twice the power level of the Micro Cell AP and the signal levels inside the cell must be the same to maintain the same data rates. Therefore:

$$P_1 = 2P_2$$

$$S_1 = S_2$$

Substituting these values in the RF propagation equation we get:

$$K2P_2/r_1^4 = KP_2/r_2^4$$

$$(r_1/r_2)^4 = 2$$

$$r_2/r_1 = 1/2^{(1/4)} = 0.84$$

The ratio, r_2/r_1, is then used to calculate how many Meru cells and Micro cells are needed to cover a given area. From these calculations is it determined that 29% less APs are required in the Meru Virtual Cell network.

The main point is that the Meru Virtual Cell network operates with 29% less APs but has higher overall performance and capacity than the Micro Cell network, because 802.11 uses adaptive modulation that adjusts the data rate based on the SNR. The noise levels are the same in both the Virtual Cell and the Micro Cell networks, however, the radius of the

Virtual Cells are larger[1] than the Micro Cells. Therefore, if the cells are engineered such that the minimum data rate is 24 Mbps, then there will be a larger area in the Meru cell that achieves rates above 24 Mbps (up to 54 Mbps). This translates to a larger area in the facility with data rates above 24 Mbps., These higher rates translate to higher overall capacity in the network because Meru schedules network traffic to avoid CSMA collisions. This phenomena is more pronounced in 802.11n networks where maximum data rates are 160 Mbps. That is larger areas operate at higher data rates without collisions increasing overall network capacity.

The second reason that the Meru network is more cost effective than the Micro Cell network is that RF design and planning is straight forward for the Meru solution. In a Micro Cell network it is important to choose optimal locations to place APs such that there is adequate SNR to achieve data rates of 24 Mbps or higher. APs must be placed in a dense Micro Cell configuration because APs are operating at low power levels. In addition, walls, furniture, and other irregularities in buildings cause RF propagation and multipath problems. This means that a detailed RF site survey must be carried out and a RF engineer must design the network such that APs are placed in optimal locations and channels are assigned such that interference is minimized and system capacity is maximized. The Meru network avoids many of these problems because all APs transmit at full power levels and co-channel interference is managed by the central controller. The cost of RF design and planning, therefore, is lower for the Meru network than for an equivalent Micro Cell network.

A TCO model is used to compare these two solutions. The following assumptions are used to drive the model:

- Meru APs transmit at 100mWatts
- Micro Cell APs transmit at 50 mWatts
- Meru cell diameter is 70 feet
- Micro Cell diameter is 59 feet[2]
- Office space used in the analysis is 250,000 Square Feet
- AP wiring and installation costs are $250 per AP
- POE port costs are $35 per port

Comparison of Meru Virtual Cell and Micro Cell 802.11a/b/g Networks

Using the assumptions above the cost of Meru approach and the Micro cell network[3] are compared and the detailed results are presented in Table 3. These results show that the Meru solution has both lower equipment costs as well as lower engineering and

[1] The Meru cell radius is approximately 70 feet while the Micro Cell radius is less than or equal to 59 feet.
[2] This value is calculated using an RF propagation model and assuming the Meru AP transmits at 100 mWatts and the Micro Cell transmits at 50 mWatts.
[3] The Micro Cell wireless network costs are those from a leading network vendor.

installation costs. Simpler deployments lead to lower costs for RF design, AP and cable installation, and configuration testing.

We have also carried out sensitivity analysis studying how the costs vary with network size. Figure 5 presents the costs for both network architectures as a function of facility area in square feet. In all cases the Meru solution is more cost effective then the Micro Cell solution.

802.11a/b/g

	Meru Virtual Cell		Micro Cell
Network Elements			
Number of AP's		83	117
Hardware and Software Costs			
Access Points	$	28,760	$ 88,043
PoE ports	$	2,905	$ 4,095
WLAN Controllers	$	25,543	$ 45,500
Total Hardware Cost	**$**	**57,208**	**$ 137,638**
Operations Expenses			
RF Design and Planning	$	6,500	$ 32,000
Installation/Cable	$	20,750	$ 29,250
Configuration/Testing	$	2,860	$ 6,882
Maintenance Contract	$	8,581	$ 20,646
Total Services and Support Cost	**$**	**38,692**	**$ 88,778**
Total Expenses			
Total Cost of Hardware and Operations	$	95,899	$ 226,415
Total Cost Savings	**$**	**130,516**	
Ratio of Micro Cell to Meru TCO		**236%**	

Table 3
TCO Comparison of Meru Virtual Cell to Micro Cell wireless networks for 802.11a/b/g in 250,000 square feet of office space

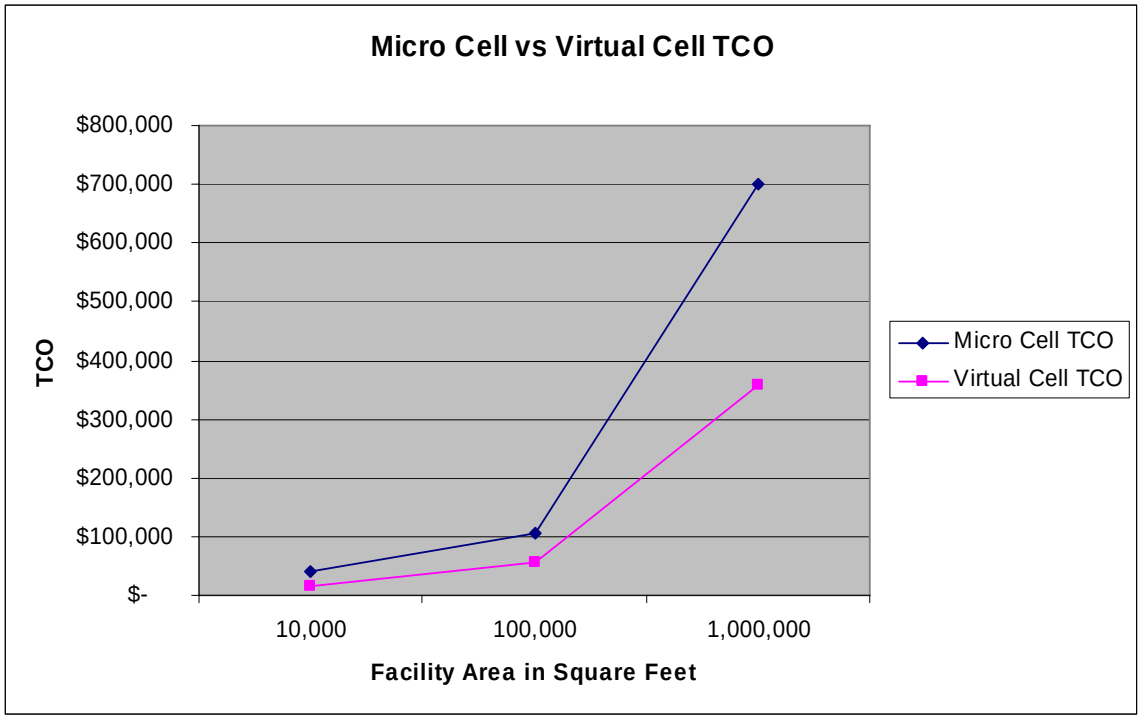


Figure 5
Comparison of Meru Virtual Cell and Micro Cell Architectures as a function of Office Area

Comparison of Meru Virtual Cell and Micro Cell 802.11a/b/g Networks

A comparison of the Meru network architecture and the Micro Cell architecture for 802.11n networks is presented in Table 4. The primary difference between the 802.11a/b/g and the 802.11n networks is the cost of the AP's and also the cost of RF engineering. In the 802.11n network RF engineering is complicated by the fact that signal propagation and cell geometries are more complex then the 802.11a/b/g networks.

802.11n

	Meru Virtual Cell		Micro Cell
Network Elements			
Number of AP's	83		117
Hardware and Software Costs			
Access Points	$ 69,430	$	106,061
PoE ports	$ 2,905	$	4,095
WLAN Controllers	$ 25,543	$	45,500
NMS Hardware and License	$ 35,990	$	78,950
Total Hardware Cost	**$ 133,868**	**$**	**234,606**
Operations Expenses			
RF Design and Planning	$ 6,500	$	32,000
Installation/Cable	$ 20,750	$	29,250
Configuration/Testing	$ 6,693	$	11,730
Maintenance Contract	$ 20,080	$	35,191
Total Services and Support Cost	**$ 54,024**	**$**	**108,171**
Total Expenses			
Total Cost of Hardware and Operations	$ 187,891	$	342,777
Total Cost Savings	**$ 154,886**		
Ratio of Micro Cell to Meru TCO	**182%**		

Table 4
TCO Comparison of Meru Virtual Cell to Micro Cell wireless networks for 802.n in 250,000 square feet of office space

Conclusion

The Meru Networks Virtual Cell Architecture has advanced the state of the art in WiFi networking creating a network of Access Points that appear to WiFi clients as a single virtual AP. The Meru controller uses advanced, standards-based techniques to schedule WiFi access allowing all APs to transmit on the same channels at maximum power levels. Co-channel interference, and CSMA collisions are mitigated by intelligent controller coordination of WiFi transmission. Meru also provides QoS for both transmit and receive, allowing for full integrated voice and data transmission across the WiFi network.

This paper has used ROI models to demonstrate that:

- Meru's technology allows enterprises to reliably replace wired networks with wireless providing substantial savings due to elimination of wiring and wired LAN expenses.
- The WiFi Virtual Cell Architecture is more cost effective than the Micro Cell Architecture

The savings in both these areas have been quantified and are substantial.