WLAN Total Cost of Ownership: Comparing Centralized and Distributed Architectures

A Farpoint Group White Paper

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During their relatively brief history, wireless LANs have faced a remarkable number of challenges, each one a nail in their coffin according to assorted industry critics. First came the issue of throughput, largely addressed by the 802.11b, a, and g standards, and with an even faster 802.11n spec due in the not-too-distant future. Then came concerns regarding product price, but the combined magic of VLSI, standards, and competition have cut the price, for example, of client devices by more than 95% in the past decade – to the point where they're almost free. Then arose the widely-noted problems relating to security, and these too have been addressed, by the Wi-Fi Alliance's Wireless Protected Access (WPA) specification, the upcoming 802.11i standard, virtual private networks, third-party "enhancer/completer" hardware, and significant architectural advances such as those embodied in the now-mainstream centralized wireless-LAN systems that we'll discuss in more detail below. In every case, WLANs have met challenges related to growth, reliability, and suitability to networking environments and missions across the board, in both vertical and, especially today, horizontal (general office) applications.

With demand for these general applications of WLANs seeing tremendous growth in both enterprise and public-space deployments, one additional issue is now coming to the forefront – the issue of *cost*, and, more specifically, how to evaluate and minimize the *total cost of ownership (TCO)* of a given wireless-LAN installation. As it turns out, this is not an easy task for engineers, network operations staff, or finance departments alike. The variables involved can be complex, and, in some cases, difficult to quantify. The core drivers for WLAN installation today are the convenience (and thus the resulting productivity improvements) of going wireless, and the fact that a network connection can be made available under substantially similar conditions for enterprise, public-space, and even residential environments – all without the need to find a place to plug in, a factor that completes the justification for having a mobile computer or communicator in the first place. We are also seeing, thanks to the drop in cost noted above, a proliferation of wireless client devices and mobile computers of all forms equipped, by default, with Wi-Fi capabilities. This trend is accelerating and is one that promises to maintain if not increase demand for WLANs for the foreseeable future.

But perhaps most significantly, advances in WLAN architecture are resulting in a continuing stream of new products that *centralize* and *integrate* all required WLAN functionality, security, management, and performance, while offering significantly lower TCO in the bargain. Farpoint Group has advocated the use of products based on centralized architectures from their inception in late 2002. The purpose of the White Paper is to explore how the architectural features of centralized systems can have a positive and significant impact on the total cost of ownership of WLAN systems in the enterprise.

A Framework for Total Cost of Ownership

The term *TCO* is frequently applied to quantify the bottom-line costs associated with any equipment acquisition over the life-cycle of its installation and use. In general, it is the *net cost (expense) accumulating over the useful life of any given purchase.* There are two key elements in the calculation of TCO: *Capital Expense (CAPEX)*, and *Operational Expense (OPEX)*. CAPEX includes the cost to acquire the various items of equipment (mostly hardware) required. OPEX includes the labor involved in initial installation and configuration, as well as all ongoing management, maintenance, and costs related to network reconfiguration dictated both by growth and the resolution of physical-plant problems. Over time, CAPEX is overwhelmed by OPEX, because capital equipment costs decline rapidly with advances in technology while OPEX tends to be labor-intensive and thus more likely to increase in the absence of technology-related cost mitigation. Regardless, it's important to consider both elements carefully.

From the above, we can form a basic model for the TCO of WLANs, as follows:

TCO = Cost of equipment required [CAPEX] +
Cost of equipment installation [OPEX] +
Cost of network maintenance [OPEX]

Note that CAPEX includes not just WLAN equipment, but also possibly other network equipment such as management appliances, VPN hardware, firewalls, intrusion detection and prevention gear, network monitoring and control hardware and software, and even additional routers and switches. Installation costs can include planning, configuration, physical installation of equipment, and provisioning. Maintenance includes RF spectrum management capabilities (which we'll cover from a cost perspective in more detail below), AP maintenance (of particular concern in distributed implementations), and even changes to an existing wired infrastructure that might be required.

Many WLAN TCO discussions have to this point included a variety of other cost factors. While there is always some administrative overhead in making any purchase (in the form of defining product requirements via a Request-for-Information/Request-for-Proposal (RFI/RFP) process, proposal evaluation, product evaluation, product selection, end-user training, and the overhead of having a purchasing department, among a few others), we do not consider these costs here because they are not unique to wireless LANs and indeed apply to any network or other technology purchase – and moreover are largely unaffected by WLAN architectural choice. Similarly, there are usually end-user support expenses, including documentation and Help Desk, but these too are common to both wired and wireless networks. But - minimizing the number and types of WLAN and related equipment installed can have a very positive effect on operations-related expenses.

We should also point out here that, while the two terms are often used interchangeably, TCO is *not* the same as *Return on Investment (ROI)*. ROI is here defined as the present value of an investment minus its total cost (or TCO). TCO is therefore a major *component* of ROI but the two are not equivalent. The productivity improvements gained from anytime, anywhere, on-demand wireless access to information, in our opinion, have a remarkable if not mission-critical effect on ROI. Regardless, minimizing TCO can only have a positive effect on ROI.

Finally, the huge decline in the cost of WLAN client devices and the increasing frequency of inclusion of Wi-Fi capability into these devices now result in only a very minimal cost premium for clients. We see most notebooks and many PDAs and even cell phones equipped with WLAN functionality as a standard feature or low-cost option over the next year. Regardless, for purposes of our comparative analysis of the impact of WLAN architecture on TCO, client costs are identical in both cases, and therefore need not be considered in the analysis itself.

Architecture and TCO

Perhaps the most significant development in the evolution of the wireless LAN (after, of course, the invention of microcellular networks that have enabled dynamic geographic roaming) is the movement to *centralized* WLAN architectures. Traditional WLANs, which we refer to as having a *distributed* architecture, have been based on a network of independent and essentially autonomous *access points (APs)*, each connected to a (typically) wired backbone network and acting as a bridge between wireless users and the rest of the network infrastructure. Centralized (often called *switched*) architectures, on the other hand, use what is essentially a collapsed backbone approach via a hardware component (or *appliance*) commonly referred to as a *wireless switch* managing some number of "thin" APs - so called because they implement far less local processing than traditional distributed APs. All addressing, management, roaming, and security, among other functions, are centralized in the switch, with the thin APs acting purely as radios and bridges.

The primary TCO benefit of the centralized approach is a significant reduction in OPEX due to decreased costs involved in configuring and managing each AP as a separate network element. A secondary benefit to centralization is the reduction in CAPEX due to lower AP costs over time, and the greater integration of WLAN-specific functionality in the wireless switch. Thin APs involve less local processing and therefore will have lower component costs over time. Moreover, efforts are now underway to standardize both the functionality of thin APs as well as the communications protocols involved in thin AP/wireless switch connections; these developments should also result in lower costs. Even when amortizing the cost of the hardware elements involved, centralized architectures can still have a fundamental cost advantage over conventional distributed models.

The Bigger Picture: Wireless vs. Wired

Many potential WLAN customers are still wondering how the cost of a WLAN infrastructure compares to *wired* networks. Given that wired LANs do not support mobility, the most important element in any wireless solution, such a comparison could in fact be moot. But even if we look simply at the costs associated with this comparison and ignore the unique benefits of wireless entirely, we still find that, in most cases, wireless is regardless the better value with a superior total cost of ownership.

The reason for this is that the expenses associated with the life-cycle management of a wired infrastructure are heavily biased by operational expense. These costs in particular include those associated with the moves, adds, and changes to network infrastructure related to normal and expected network reconfigurations over time, as well as the lost productivity resulting from the lack of network availability while waiting for a new or repaired connection.

Consider the following simple framework for performing this analysis (Table 1; green shading indicates inputs to the model):

Wired Network Data		
Number of end nodes:	50	
Cost of wired LAN NIC:	$0	Assume built-in
Hub/Switch cost (per port)	$50	
Cost to add wired port:	$450	Labor and materials
Cost to move/change wired port:	$300	Labor and materials
% of ports moved annually:	42%	Typical
Lost-productivity due to move/change downtime	$500	

Wireless Network Data		
Number of access points required:	10	Need to consider coverage and capacity
Cost of access point:	$795	
Cost to install each access point:	$250	Labor and materials
Cost of wireless LAN NIC:	$75	

Wired Cost Calculation	**Installation**	**Year 1**	**Year 2**	**Year 3**
Annual cost of wired net	$25,000	$16,800	$16,800	$16,800
Cumulative cost of wired net		$41,800	$58,600	$75,400

Wireless Cost Calculation	**Installation**	**Year 1**	**Year 2**	**Year 3**
Annual cost of wireless net	$14,200	$0	$0	$0
Cumulative cost of wireless net		$14,200	$14,200	$14,200

Cost Differential (Savings from Wireless)	**Installation**	**Year 1**	**Year 2**	**Year 3**
Per network - annual	$10,800	$16,800	$16,800	$16,800
Per network - cumulative		$27,600	$44,400	$61,200
Per network node - annual	$216	$336	$336	$336
Per network node - cumulative		$552	$888	$1,224

In this example, note that the only expenses associated with installing and maintaining a WLAN physical plant are those related to initial equipment acquisition and installation. Wire, on the other hand, has major expenses associated with both maintenance and downtime. Even in this simple example, using fairly expensive access points, the cost benefits of wireless are remarkable.

Thus, given the high cost of labor associated with the life-cycle configuration and re-configuration of wired LANs, WLANs can be much more cost-effective even when the benefits of mobility are ignored. As is typical, OPEX has overwhelmed CAPEX – the requisite labor is much more expensive, especially over time, than the capital equipment, and wire exacerbates this factor. The lower life-cycle cost of WLANs are thus a key motivator for their adoption regardless of WLAN architectural choice.

We would in fact say that it's now likely that WLANs will become the *default* LAN in the enterprise. The reasons for this are many and extend well beyond a beneficial TCO – the availability of WLANs as standard equipment thanks to Intel's Centrino and related implementations, the availability of WLANs in PDAs and (soon) some cell phones, improved battery life due to power-conserving WLAN implementations, higher throughput due to new WLAN standards, and good security solutions, to name but a few. Improved ROI as a function of the productivity gains inherent in mobile access to information, however, is likely to be the key to most initial-installation decisions.

At this point, however, we must introduce a few additional costs related to wireless LANs of any form. These include an enhanced requirement for security, including airlink encryption, user-based (as opposed to location-based) authentication, wireless intrusion detection, rogue access point detection and neutralization, and, in many installations, fault-tolerance required throughout the wireless network. And these factors thus introduce additional requirements that can again have a negative impact on TCO unless handled in a cost-effective manner in the wireless LAN system of choice. As can be seen in the Table below (Table 2; green shading indicates inputs to the model), the much lower CAPEX (due to functional integration) and OPEX (due to centralized management and control) of the centralized model have a profound impact on TCO over time. Note particularly the reduction in OPEX in terms of both installation and maintenance costs.

CAPEX Components	**Centralized**	**Distributed**
Access Points	$495	$795
WLAN Switch	$8,000	$0
WLAN Management Appliance	$0	$8,500
VPN Termination	$2,000	$4,000
Firewall	$0	$4,000
WLAN Intrusion Detection, Security, Management	$5,000	$10,000
OPEX Components		
Installation Costs *(per AP)*		
AP Planning and Configuration	$0	$200
AP Installation	$250	$250
AP Provisioning	$0	$200
Maintenance Costs *(per AP)*		
RF Spectrum Management	$0	$200
AP Maintenance	$50	$250
Changes to Wired LAN Infrastructure	$0	$200
Number of Access Points	16	16
Capital Expense (CAPEX)	$22,920	$39,220
Operating Expense (OPEX)	$4,800	$10,400
Total Cost of Ownership	$27,720	$49,620
Number of Access Points	48	48
Capital Expense (CAPEX)	$38,760	$64,660
Operating Expense (OPEX)	$14,400	$62,400
Total Cost of Ownership	$53,160	$127,060
Number of Access Points	96	96
Capital Expense (CAPEX)	$62,520	$102,820
Operating Expense (OPEX)	$28,800	$124,800
Total Cost of Ownership	$91,320	$227,620

Centralized Architectures and TCO: A Closer Look

Once the superior TCO of the centralized approach is accepted, the next step in our analysis is to consider key product features required in centralized implementations that have an inherently positive impact on TCO. Note that these features are not included or even possible in all centralized implementations. Among the most important are:

- *Robust, integrated security* – no network, especially one based on wireless, is really a network unless it is secure. By this we mean that eavesdropping and unauthorized network access are made as difficult as possible without impeding use by legitimate users of the network. A complete wireless security solution should include a firewall (since the WLAN really is at the edge of the network and thus at a place where unauthenticated users will attempt to gain entry), wireless intrusion detection (identifying traffic that represents an attack on the wireless network from simple hacking to denial of service), rogue access point detection (to find and neutralize access points set up often with the best of intentions, perhaps, but still representing a security hole that must be closed), access to authentication databases (such as RADIUS), airlink encryption (based at a minimum on the Wi-Fi Alliance's Wireless Protected Access (WPA) specification, and the upcoming 802.11 standard), and higher-level encryption of the form provided in virtual private networks (VPNs). While all of these functions are of course available in separate and distinct products, a TCO-effective WLAN implementation must include *all* of these within the centralized architecture and the *minimal* set of products required for a complete solution. Moreover, all of the above functions must be implemented with performance (in terms of throughput and capacity) as a paramount consideration, since a centralized architecture that runs out of capacity will require additional CAPEX to correct the problem – price/performance remains an important consideration always.

- *Seamless Mobility* – establishing routing across subnets has always been a key challenge in wireless LANs. Centralized architectures however, can easily manage this core function since they directly see all access points (and thus all mobile users) and can apply mobile IP techniques transparently with respect to the rest of the network. Of particular importance, however, is the requirement that the connection between the APs and the central wireless switch be based on IP. This enables the cost of the switch to be amortized across a much large number of APs than is possible in the case where the switch must be directly connected to a given AP. Management expense is also lowered - implementing a centralized wireless LAN system reduces the number of required components, provides addressing across the entire wireless network with no changes to core routers (very important in mitigating the risk always inherent in any additions or modifications to an operational network), and thus has a dramatic affect on TCO.

- *Wired-LAN/Wireless-LAN Integration* – It's critical that wireless LANs be added to an existing wired LAN in a manner that is *non-disruptive* – essentially as an overlay to the current infrastructure, seamlessly integrating with current wired functionality. For example, Virtual LANs (VLANs), a key method of providing differentiated services, prioritization, and elements of a complete security solution, must implemented in the wireless switch itself to avoid impacting currently operational systems. The ultimate test of wireless LAN implementation is its installation and operation with *no* changes (physical or logical) to the rest of the network infrastructure – perhaps the most important cost minimization of all.

  Other factors here include support for 802.3af Power over Ethernet (PoE), direct support for Mobile IP (eliminating the need to enable core routers to support this requirement), and direct support for layer-3 routing and layer-2 switching, again independent of the wired infrastructure. The overriding goal here, again, should be wireless implementation without introducing new risks to network stability, security, and operations

- *RF Spectrum Management* – Whereas classic network management, dealing with such matters as status and performance monitoring, user authorization, and unusual or alert situations, remains critical in wired and wireless networks alike, wireless LANs have an additional challenge and opportunity – *the management of the airwaves themselves*. Since wireless LANs use unlicensed spectrum, operations staff can never

be sure of the nature of this virtual wire in the sky at any given moment in time. But RF spectrum management features included in the wireless LAN system itself can be used to dramatically lessen the management and operations load inherent in older and less-robust wireless LAN products. For example, WLANs can be made self-configuring, self-calibrating (to the environment, both physical and radio-spectrum related), and self-healing in the event of equipment failure. In the past, labor-intensive site surveys were required to determine coverage with a given installation - and may still be required with some distributed products. But such work is now unnecessary. An installation can be performed with a basic knowledge of building layout and expected traffic loads, and then RF spectrum management features can inform operations staff of gaps in coverage, oversubscribed access points, and a wide variety of other conditions. RF spectrum management, of course, is but one element of the overall wireless network management capability implemented in the switch. All WLAN management and administration functions are centralized in one place, even across the multiple switches that might be required in larger configurations (and desirable nonetheless for reasons of fault tolerance – automatic failover is a key feature in any mission-critical installation). Finally, a network that can monitor itself eliminates the need for specialized handheld and other analysis tools – this functionality, while important if not critical, needs to be included in the core WLAN product and not obtained external to it. It should be possible to find, analyze, and correct problems within the wireless network without actually having to send someone with a handheld tool to the suspected location in the network, and centralized RF spectrum management tools make this possible. The bottom line – network maintenance costs are minimized, further enhancing TCO.

For more information on the whole subject of RF spectrum management, see Farpoint Group White Paper 2003-201.1, *Beyond the Site Survey: RF Spectrum Management for Wireless LANs*.

In summarizing all of the above, overall cost-to-solution, and thus TCO, can be heavily influenced by architectural and specific product choices. As can be seen in Table 2, centralized architectures offer much better TCO, and the choice of specific centralized product can further enhance TCO – significantly – via the inclusion of required features and simplifying interconnection with existing wireless networks.

Meeting the TCO Challenge

The term “doing more with less” is one of the more visible artifacts of the last economic recession, which is now thankfully in the past. But network managers, operations staff, and financial managers alike all agree that the squeezing more productivity out of networks, both wired and wireless, is simply a good business decision. Indeed, successful wireless LAN products will be defined by their adherence to this dictum — and we believe, for reasons outlined in the White Paper, as well as many others — that centralized architectures will dominate the WLAN scene. If total cost of ownership is to be minimized, the product features noted above must be integral in whatever product is selected. The minimization of operating expense, through integrated security, transparent mobility management, minimal (if any) disruption to the wired portion of the network, and RF spectrum management are the keys to the best possible TCO – and while we’re at it, maximizing ROI.

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