HEAVY READING

White Paper

Making the Case for Remote PHY

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Introduction: Facing The New Virtual Reality

With their access networks facing swiftly growing capacity crunches and cost pressures over the next few years because of customer demand for gigabit broadband service, IP video, WiFi hotspots, business services, Ultra HD video and other high-bandwidth services, cable technologists are increasingly counting on decentralization and virtualization to save the day.

From CableLabs to multiple system operator (MSO) labs to vendor labs throughout the world, industry engineers are particularly exploring several innovative approaches for spreading out and virtualizing key equipment and network functions that have historically been lodged in the cable headend. The various distributed access architecture (DAA) approaches range all the way from moving parts of the cable modem termination system (CMTS) and edgeQAM modulator, or a combined Converged Cable Access Platform (CCAP) system, from the headend to the fiber network edge, to shifting all of the parts to the network edge and completely eliminating the entire physical platform in the headend.

Each of these proposed DAA approaches for transforming the cable access network has its own distinct pros and cons. At the same time, though, all of the approaches share at least some of the same potential benefits and drawbacks, making it difficult to choose among them, at least at first glance. As a result, the great brewing debate over DAA is now starting to heat up, with no industry consensus yet forming around any one leading approach.

But one thing does seem very certain: As cable operators grapple with ways to enter the Gigabit Era, upgrade to all-IP service delivery, meet the increasingly higher bandwidth demands of customers, ease the burden on their already strained networks, cut soaring power, energy and other costs, clear space in their ever more congested headends and generally boost their operating efficiencies, they must start shifting at least some of the traditional headend components to the network node. With such network transformation a given, the big questions are really which components to shift and when.

This white paper explores these questions and more, delving into the forces that are driving cable operators to decentralize and virtualize their headends and infuse more intelligence in their networks. The paper examines the various distributed architecture options that the cable industry is considering and spells out the benefits and challenges of taking the distributed route. It addresses the key factors that cable providers should consider when deciding what to distribute, and when and where. And the paper explains why Casa Systems, like several other major equipment vendors, believes that a standards-based Remote PHY approach offers the most logical first step for MSOs considering network transformation.

The New Cable Landscape: Upheaval & Change

In this section, we'll look at the main forces that are driving cable operators to carry out this historic transformation by re-architecting their access networks and moving toward some form of distributed CCAP. As touched upon in the introduction, these drivers range from the launch of gigabit broadband services and the embrace of IP video to the rapid rollout of WiFi and the strong growth of business and wholesale services, among others.

The introduction of gigabit broadband services is one obvious business driver. With MSOs across the globe now preparing to roll out the industry's new DOCSIS 3.1 specifications, cable providers will have the technical ability to offer downstream data speeds as high as 10 Gbit/s and upstream speeds of 1 Gbit/s or more. But to actually deliver those kinds of blazing speeds to customers, cable providers will need much higher bandwidth capacity, more processing power and greater operating efficiencies. They will also need a more flexible architecture that enables them to switch QAM channels from video delivery to data delivery and back.

Another major factor is cable's growing adoption of IP video. As cable operators start to shift more and more of their video services to IP delivery, they will need more capacity to carry the unicast signals to subscribers and simulcast their programming over both QAM and IP channels. That migration calls for more storage and processing closer to the network edge, where the services can be delivered more quickly and efficiently to subscribers.

Space constraints in cable headends and hub sites are another major business driver for a more distributed approach, just as they have been a major driver for integrated CCAP. With headends and hub sites getting more and more congested with bulky equipment, cable providers are looking for ways to spread the load through their access networks. Providers are also looking for ways to reduce the number of hub sites to generate both capex and opex savings.

Besides clearing space in headends and reducing the number of hub sites, cable operators are seeking to push capacity to demand epicenters such as multiple dwelling units (MDUs) and hotels in a more granular way than their current approaches allow. They are also seeking to shift network capacity to existing and potential revenue hotspots – such as small to midsized businesses (SMBs), again in a more targeted fashion than they can do today. The cable network has no equivalent of the mobile network distributed antenna system (DAS) or small cell, no equivalent of the WiFi hotspot. Thus, some form of DAA makes a great deal of sense.

The industry's increasingly rapid rollout of WiFi is yet another big driver: With at least 15 million cable WiFi hotspots now deployed in the U.S. alone, cable operators have quickly developed their own nationwide wireless network potentially capable of competing against the formidable cellular networks built by AT&T, Verizon, Sprint and T-Mobile. But the explosive growth of WiFi use by cable customers is placing yet another burden on the industry's already strained broadband networks.

Cable's steady growth in business and wholesale services is a major contributor as well. Looking just at the U.S. again, commercial services now generate more than $12 billion in annual revenues for the industry – 10 times what it did less than a decade ago. Yet, even with the construction of substantially more fiber lines over the last few years, cable providers are finding it difficult to keep up with the surging demand for these bandwidth-intensive services.

On top of these already well-established drivers, the upcoming launch of Ultra HD/4K TV service and the emergence of the so-called Internet of Things (IoT) are likely to add significantly to the cable capacity crunch. In the case of bandwidth-chunky UHD, for instance, it's estimated that a single channel will require 15 to 20 Mbit/s to deliver to a subscriber TV, set-top box, tablet or other viewing device. That's a whole other order of magnitude for cable operators used to squeezing many more standard digital or ordinary HD channels into the same amount of bandwidth.

Finally, ironically enough, one more potential driver for the migration to distributed CCAP is the ongoing introduction of integrated CCAP technology. By combining the traditional data processing functions of the CMTS and video processing functions of the edgeQAM modulator in one dense, centralized device in the headend, integrated CCAP is making it easier for cable operators to look at splitting up those functions into different modular components. In turn, that should make it easier for operators to virtualize the equipment and shift some or all of the components into the network.

Given all of these drivers, the cable industry is clearly entering a period of great technological upheaval and change. The big question is, how will cable operators choose to respond? The next section lays out the main options that cable technologists are now exploring as they contemplate the industry's distributed future.

DAA: The Benefits & Main Options

With all these existing and potential drivers pushing cable operators to consider overhauling their basic access architectures, the DAA concept has become a hot topic of discussion in cable engineering circles. Over the past couple of years, cable technologists have been increasingly examining and debating various options for relieving the growing strain on the cable infrastructure by shifting at least some of the central headend equipment and functions to the access networks and virtualizing them in the cloud. In this section, we explain the benefits of a more decentralized approach and lay out the main options for pursuing it.

DAA promises several major benefits for MSOs. One critical advantage is that DAA keeps the cable data and video signals in digital format as long as possible, extending the digital signals beyond the headend deep into the network node before converting them to analog. The distributed approach accomplishes this feat by replacing the analog forward link between the headend and the access network with a more advanced digital forward, or "digital fiber," connection. This switch to digital optics produces signals with a higher signal-to-noise ratio, meaning less signal interference.

Due to this change, cable operators can support higher QAM modulation rates and pack more bits per hertz into their networks, making those networks both notably faster and more spectrally efficient. Such enhancements are especially essential for the rollout of DOCSIS 3.1 and the much higher data speeds that it can deliver.

Another benefit of DAA is improved reliability of the optical link between the headend and network. While analog optical links can be hurt by environmental conditions and require periodic maintenance, Ethernet optical links are far more durable and require much less maintenance, so they perform more reliably than analog links.

DAA also enables MSOs to leverage longer distances between the headend and the node. That's because digital interfaces, such as the Ethernet links contemplated for use here, are designed to operate over much longer distances than their analog counterparts. MSOs can take advantage of these longer distances to move key functions and services deeper into their networks, freeing up space in the headend.

In the process, MSOs can use the new digital forward links to drive Ethernet much deeper into their networks. As a result, they can use IP-based technology to deliver data, video and potentially other services all the way to the node, rather than just to the headend, before converting signals to analog for the last stretch to the customer.

Moreover, the new digital fiber link can support more wavelengths than the old analog connection. Thus, it can help MSOs upgrade to a more "fiber deep" architecture, enabling them to set up more fiber nodes and create smaller service groups. In turn, this will make it easier for MSOs to make the eventual migration to all-fiber networks.

Finally, DAA allows MSOs to start virtualizing different headend and network functions and placing them in the cloud. As a result, it could become the cornerstone of the industry's emerging network functions virtualization (NFV) strategy, enabling further reductions in capex, space and power requirements. It should also make it easier and more efficient for cable operators to deploy such advanced broadband specs as DOCSIS 3.1 and whatever may follow it.

It's not surprising, then, that cable technologists generally agree that a DAA approach makes great sense for the industry's future. Working with this general concept, they have crafted several options for carrying it out. The big question now is which approach makes the most sense to deploy first.

Specifically, CableLabs has defined three different DAA approaches: Remote PHY; Remote MAC-PHY (which can have two incarnations – Remote CCAP or Remote CMTS + Divided EQAM); and Split MAC. So far, Remote PHY and Remote MAC-PHY have gained more traction in the U.S. and in Europe than the Split MAC option.

Remote PHY is probably the leading option under discussion right now. Under this approach, the PHY layer of the integrated CCAP device (or CMTS and edgeQAM) is split off from the CCAP core (or CMTS core and edgeQAM core) chassis in the headend and shifted to a new Remote PHY Device (RPD) at the optical node in the network. As defined by CableLabs in a recently issued series of specs, Remote PHY represents an evolution of the Modular Headend Architecture specs originally issued for the modular CMTS (M-CMTS).

Consisting mainly of PHY-related circuitry, such as downstream QAM and OFDM modulators and upstream QAM and OFDM demodulators, the RPD is a PHY device that converts downstream DOCSIS data, MPEG video and out-of-band (OOB) signals from digital to analog one way and upstream data, video and OOB signals from analog to digital the other way. The technology uses pseudowires between the headend and the network node to connect the RFP devices to the CCAP core.

The second alternative under consideration by cable technologists is known as Remote CMTS + Divided EQAM. Taking the decentralization idea further than Remote PHY, this approach shifts both the PHY modulation function and part of the edgeQAM functions from the headend to the optical node at the network's edge. But the edgeQAM functionality is divided between the headend and the remote node. CableLabs issued a technical report spelling out this method in July 2015.

Going even further than the first two options, the third main approach is called Remote MAC/PHY with all of the edgeQAM functionality shifted to the fiber node. Under this most radical approach, no core device is left in the headend at all because all of the signal processing and modulation occurs in the access network. The only thing that remains in the headend is an aggregation router. CableLabs issued a technical report spelling out this method as well in July 2015.

Other versions of these three distributed architectures, including variants that would split the PHY and/or MAC functions between the headend and the network, have also been circulating among cable engineers. But these three versions have emerged as the leading options so far. As mentioned earlier, each has its pros and cons.

Figure 1: How Leading DAA Options Stack Up

	Remote PHY	Split MAC	Remote MAC/PHY	
			Remote CCAP	Remote CMTS + Split EQAM
Remote Node	PHY Device, PHY Only	Remote CMC, Partial MAC & PHY	Remote CCAP, MAC & PHY	Remote CMTS, EQAM PHY
Core	CCAP Core (CMTS Core & EQAM Core)	Controller, Router OLT + Classification	Controller, Router, OLT/Ethernet	EQAM Core
Digital Fiber Link	Supported	Supported	Supported	
Standards	Fully specified by CableLabs	Technical report issued by CableLabs	Technical report issued by CableLabs	

Key Factors to Consider

With several different flavors of DAA from which to choose, cable operators may be scratching their heads in confusion over which flavor to try first. But there is a way of sorting through the various choices. This section suggests several factors that MSOs should consider when deciding which distributed architecture route to take.

The first key factor that cable operators should weigh is the cost of both deploying and managing each distributed solution. Total cost of ownership (TCO) should take into account not just the physical equipment needed for the remote nodes, but also all costs associated with the replacement of any required management tools. For instance, Casa Systems says that its Remote CCAP Node (RCN) can be managed using CMTS command-line interfaces just like any other CMTS, thereby reducing TCO.

By evaluating TCO, not just the costs of equipment deployment, cable operators will be able to develop a clear understanding of their combined capital and operating expenses. Without such an evaluation, operators will not be able to budget and plan effectively.

At the same time, cable providers should look at how much revenue each distributed approach could generate for them. By gauging the potential revenue gained, they can gain a strong sense of what the return on their investment will be and shape their expectations accordingly. Even more importantly, they will be in a much better position to determine whether the investment is even worth making in the first place.

Third, cable operators should examine the upheaval factor. This means looking at how much change will be required to carry out the network transformation and whether their company is ready to make that kind of change. For instance, the deployment of Remote PHY alone would produce a dramatic upheaval; the implementation of Remote MAC-PHY would be even more dramatic. If cable providers aren't ready for these kinds of changes, even the most innovative technology won't make much of a difference.

Another key factor is keeping an eye toward future scalability of the cable network. Any preferred solutions should minimize the need to replace the remote nodes in the network as capacity demands continue to mount.

One more key set of factors involves practical as well as philosophical considerations about keeping the network node as simple as possible, both in terms of how many times it will need to be touched, as well as in terms of energy requirements and security. Because a node is not as secure a location as a headend, cable operators will likely want to minimize the electronics placed in the node.

Plus, since there are many more remote nodes than headends, operators will want to keep the power consumption down. This approach follows other access technology evolution paths – such as WiFi and remote radio head (RRH) – that have tended to keep the edge devices simple as access densification evolves.

In addition, cable providers should consider the path to virtualization that each distributed approach offers. An important question to ask here is whether the distributed approach selected today will simplify or complicate the company's future virtualization strategies. If the latter, then it's clearly not the way to go.

For example, MAC functions gravitate more easily to virtualization and have historically been changed more often as new specs come out. Many of these functions can easily be run on virtual machines (VMs) in the headend. So the question is whether it makes sense to distribute them now.

Above all, it's important to stress that that there will probably not be a one-size-fits-all solution for an MSO's entire infrastructure. Indeed, Cox has already indicated that it will be carrying out a micro-segmentation strategy to determine the best DOCSIS and fiber plan for the future. Instead of upgrading its cable networks on a regional or market level, Cox intends to do it on a node-by-node basis. (See Cable's Four Paths to Gigabit Internet.)

Figure 2: Key Factors to Consider

Factor	Considerations
Time to Market	• Has CableLabs already issued specifications for the architecture? • Does the approach use existing or planned cable devices (cable modems and STBs)?
Cost	• Does the DAA solution reduce equipment, power and space requirements in headends and hubs, thus cutting both opex and capex? • What are the hidden costs of retraining staff to use new configuration and management tools and update customer premises equipment (CPE)? • Will the approach boost opex or generate more frequent truck rolls (e.g., for upgrades)?
Scalability	• Will the DAA solution enable targeted scaling of capacity where needed? • Will the solution reduce the need to replace remote nodes as more capacity is needed?
Path to Virtualization	• Are layer functions presently candidates for virtualization per CableLabs specifications? • Are layer functions more software-centric, enabling an easier shift toward virtualization? • Will keeping more complex functions centralized right now make the ultimate virtualization path smoother?
Interoperability	• Are there already any cross-vender interoperability specifications for the DAA solution? • Do specs define interoperability between remote nodes and CCAP cores, enabling greater flexibility?
Security	• How secure are the physical locations for the complicated electronics? • How secure is the connection between the remote node and the core/data center via IPsec? • How great is the management control to guard against man in the middle attacks?

Why Remote PHY First

As noted earlier, all of the leading DAA options share several key benefits, making it difficult to choose among them at first glance. For cable operators, these benefits include keeping the cable data and video signals in digital format as long as possible, enabling higher QAM modulation rates, packing more bits per hertz into the network, boosting the reliability of the optical link between the headend and network, driving Ethernet much deeper into the networks and supporting more wavelengths, among other things.

But many leading cable technologists, including those at Casa Systems, believe that Remote PHY stands out as the distributed access option of choice, at least as the first step in the network transformation process. They provide several reasons to support their position:

- Remote PHY offers a standards-based approach to going the distributed route, thanks to the family of seven specifications and two technical reports that CableLabs drafted for the architecture and released in late June 2015. Among other things, these specs define interoperability between different CCAP core chasses and Remote PHY vendor solutions without requiring specialized development or upgrades of back-office systems. In contrast, CableLabs has only released a technical report for Remote MAC-PHY. Detailed specifications for Remote MAC-PHY are still a work in progress.
- The Remote PHY node devices, as defined in the CCAP spec, can support all of the current CCAP services. Thus, cable providers can introduce these new devices into their access networks without needing to make any further changes to their cable modems or set-top boxes.
- The Remote PHY devices promise to be more manageable than their counterparts in the other distributed architectures. For instance, the Remote PHY devices can be presented as extensions of the CCAP core and then collectively managed as if they actually formed one single giant CMTS chassis. In contrast, under the Remote MAC/PHY and Remote CCAP approaches, operators must configure and manage a much larger group of smaller CMTS devices scattered throughout the access network.
- By retaining the MAC functions in the headend, the Remote PHY architecture reduces the potential complexity and costs of the optical node in the network. Such reduced complexity will translate into fewer operational failures and, thus, fewer truck rolls for cable operators to carry out. Moreover, the Remote PHY approach has lower power requirements than the Remote MAC/PHY architecture. Indeed, the shift of the MAC functions to the network can increase the node's power requirements by as much as 30 W to 50 W per node.
- Remote PHY promises greater security than the other two leading DAA options because it puts the least amount of equipment and intelligence in the optical node, which is simply not as secure a location as either the headend or a hub. In the Remote PHY architecture, all encryption/decryption and key management is performed in the headend or hub. In contrast, these functions shift to the node in the Remote MAC/PHY architecture, promoting the need for additional security provisions to protect services.
- Remote PHY can easily support networks with different sized DOCSIS and video-on-demand (VoD) service groups. Once again, the other two DAA options cannot make the same claim.

- Remote PHY keeps the MAC functions centralized in the headend. This centralization should pave the way for the eventual virtualization of these functions, just as the development of the integrated CCAP chassis has done for the basic CCAP functions.

Given all these reasons, it makes sense for cable operators to try out the more incremental Remote PHY architecture before moving on to other DAA options. Even if they opt later on to leverage Remote MAC/PHY or Remote CCAP technologies, they can still use Remote PHY as a springboard to the other, more decentralized distributed approaches. But if they try the other approaches first, it would be difficult, if not impossible, to scale back to Remote PHY.

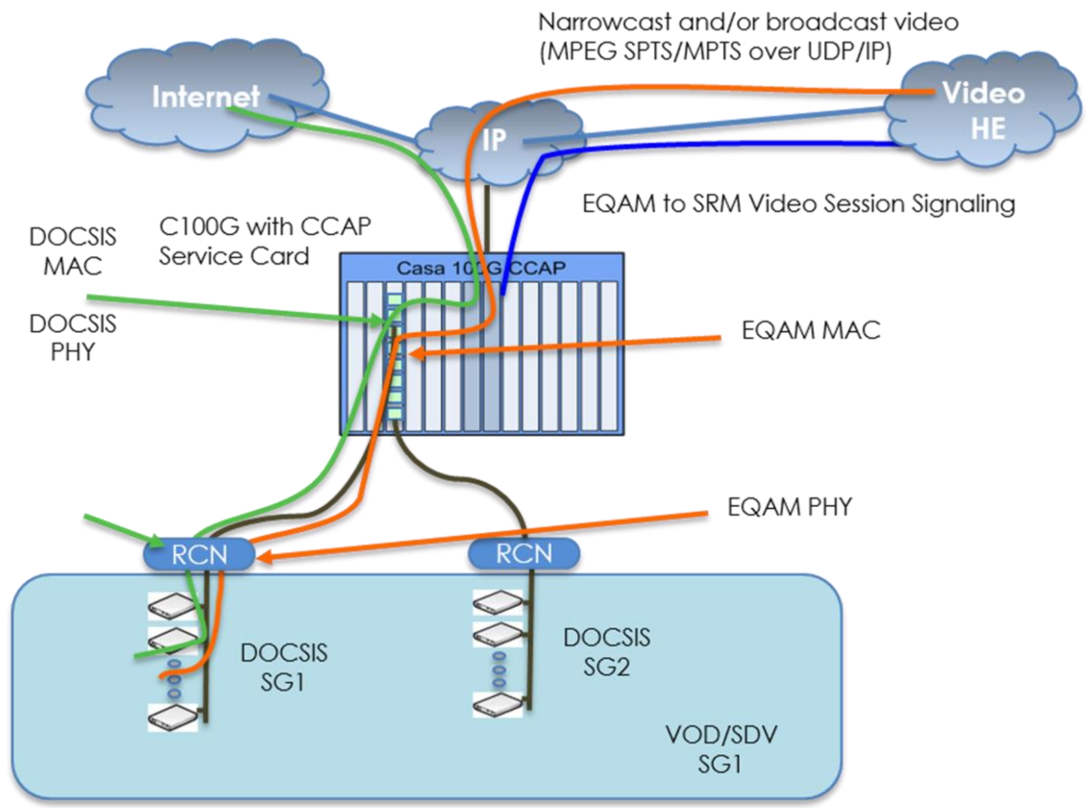
Figure 3: Why Remote PHY First

Factor	Details
Time to Market	• CableLabs specifications have already been issued for Remote PHY but not yet for other DAA approaches. • Remote PHY method uses existing/planned devices (cable modems and STBs).
Cost	• Hidden costs from retraining personnel to carry out rival approaches could increase opex, at least in the short term. • Large numbers of remote nodes required by Remote MAC/PHY could lead to increased opex if those nodes are power hungry or require frequent truck rolls (e.g., for upgrades).
Scalability	• Remote PHY would enable targeted scaling of capacity where needed. • Remote PHY would reduce the need to replace remote nodes for additional capacity.
Path to Virtualization	• PHY layer functions are not candidates now for virtualization per CableLabs specifications. • MAC layer functions are more software-centric already, enabling easier gravitation toward virtualization. • Keeping more complex functions centralized until they are virtualized may make the virtualization path more straightforward.
Interoperability	• CableLabs' Remote PHY specifications already define cross-vendor interoperability between remote nodes and CCAP cores. • Remote MAC/PHY specifications have not yet been defined, leaving its interoperability potential open to question.
Security	• Remote nodes are less likely to be situated in highly secure physical locations, making Remote MAC/PHY more of a potential security risk. • Remote PHY would secure the link between the remote node and the core/data center via IPsec and boost management control of the remote node.

Consider the following migration scenario involving Casa's Remote CCAP Node (RCN) and the corresponding CCAP Services Card (CSC) in the headend that aggregates the remote nodes. A single hybrid fiber/coax (HFC) node can be cut over very simply to an RCN (presuming the RCN is already positioned and the corresponding CSC card is already in the CCAP core) by upgrading the fiber cable in the headend and at the node. Then, if needed, more RCNs can be added to reduce service group sizes within a cluster.

In the Casa Systems solution, because a single RCN can support two Remote PHY modules, a 2x node split can be carried out by deploying one RCN. DOCSIS services can be switched over to the node independently of video services. A mixture of DOCSIS 3.0, DOCSIS 3.1 and RCN FN can be supported. There's no requirement that DOCIS and VoD service group sizes be the same. So service rollouts can be incremental, down to the node level.

Figure 4: Casa's Proposed Remote PHY Architecture



Source: Casa Systems

Conclusion

With customer demand for bandwidth continuing to surge, looming capacity problems are simply not going to go away by themselves. As the introduction of gigabit service, the growing adoption of IP video, the increasingly rapid rollout of WiFi, the steady growth of business and wholesale services and the upcoming launch of UHD/4K services places greater and greater strains on their access architectures, cable operators will need to find ways to make their networks carry more traffic and run more efficiently. Cable providers will also need to spread the load around as their already congested headends threaten to become even more packed with large chasses and other equipment.

Fortunately, help appears to be on the way. As explained in this paper, distributed access architecture solutions offer salvation for bandwidth-pressed cable providers. By shifting at least some of their traditional headend equipment and functions to the network node and cloud, providers can free up space in their crowded headends, boost the capacity of their networks, make those networks run more smoothly and more efficiently, and cut power consumption and costs. DAA also offers other potential benefits, including higher signal quality, greater reliability of the links between the headend and network, improved network performance and, ultimately, a better customer experience.

All of the leading DAA options can deliver most, if not all, of these benefits. But that doesn't mean they are all created equal. Each one offers distinct pros and cons, as spelled out in this paper.

Like many leading cable technologists, Casa Systems argues that Remote PHY offers the best bang for the buck right now because of its unique advantages. These advantages include a standards-based approach fully defined by CableLabs specs, support for all CCAP functions and services, greater manageability, less network complexity, lower operational costs and greater security. In addition, Remote PHY offers a clear path to further virtualization of the access network.

DAA is clearly a concept whose time has come for cable. Now the big question is not whether to distribute the access architecture at all, but *how* to distribute it. For the reasons stated above, Casa believes that Remote PHY makes the most sense as the first step down this much-anticipated virtualization path.