Dyband in the Cisco Internet Ecosystem

Synergy in Bandwidth Management

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Summary:

The Dyband Shaper is a network edge device that provides control, management and monitoring of bandwidth for TCP/IP networks. Software-based, it gives Network Service Providers (NSPs), enterprises, educational institutions and governments the ability to use rate policies to control and guarantee bandwidth allocation on a per-subscriber basis, even under congested conditions. The Shaper is the major component of the Dyband product suite. The other components are:

- CMon, the Dyband control terminal, policy administrator and network monitor
- Archiver, which maintains a history of bandwidth consumption.
- Miner, the reporting engine
- Profile Push, enabling central control of multiple distributed shaper policies.

Dyband's feature set is compelling for any service provider who sells or provisions tiered bandwidth to large numbers of subscribers, i.e. the Internet Service Providers (ISPs), or businesses that provide networks to large groups of distributed users from a central location or aggregation point, such as educational institutions, medium to large Enterprises, and Governments.

The Shaper is a point control device that is located between the clients and the Internet, typically just inside the Internet access router. From here, it uses optimized queuing technology to monitor and control bandwidth between IP hosts. CMon allows the network systems administrator to create and administer an unlimited number of rate policies and to apply these policies to subscribers, individually or in groups. The Shaper ensures that these policies are applied precisely under all conditions short of network failure, thereby allowing the service provider to confidently oversubscribe his WAN pipes, or the enterprise system administrator to tightly control his bandwidth and the network utilization, a fact of life in today's marketplace.

Typically, a subset of these services is included in packet-switching devices (routers and switches), but their functionality is resource-constrained. By offloading these processes to a "network appliance", Dyband adds capabilities that are beyond the reach of the typical packet switch. As such, it allows service providers and enterprises to preserve their existing network infrastructure while giving them architectural flexibility when planning expansion. Dyband's highly efficient, user- and subscriber-centric approach to bandwidth management is, so far, unique.

Dyband is a valuable adjunct to Cisco's NSP and enterprise offerings. It provides in one product, capabilities that those customers need, which are currently not included in the Cisco repertoire. With the Dyband product in its Cisco-based network, the NSP or enterprise can enhance its bottom line by providing guaranteed bandwidth allocation, on many levels, to its clients while over-subscribing its expensive Web-access pipes. These two capabilities are essential in today's competitive marketplace, if the NSP or enterprise is to differentiate itself and thereby prosper. Dyband takes the risk out of those two activities.

Introduction:

The IP services market is growing explosively. At the same time, consumers are becoming far more selective. Residential and business users are demanding not only high-bandwidth Internet access, but also guarantees of contracted service levels. This presents ISPs with a substantial business opportunity: Increase market share and revenues by offering tiered services, with increasingly stringent service guarantees, at correspondingly higher prices. At the Enterprise level, systems administrators must manage hundreds or thousands of users and fulfill their bandwidth requirements within an often heavily expenditure-constrained environment. A very small number of “bandwidth hogs” in their network can ruin the network for all users. In order to fulfill on the service guarantees, administrators have to deploy subscriber-level bandwidth management that is both flexible in rule definition and restrictive in rule application. Bandwidth management systems for today’s successful ISP and enterprise must include the following capabilities:

- Rate control over individual IP flows, using prioritized fair-queues
- Real-time monitoring of bandwidth consumption
- A variety of bandwidth controls, including time-of-day shaping
- A highly flexible subscriber rate policy configurator
- Archiving/reporting of per-host bandwidth consumption

Dyband fulfills the enterprise need to control and monitor traffic on a per-subscriber basis and offloads the process to a discrete device. This allows the routers and switches to apply CPU and memory resources to their primary purpose of packet switching, thereby improving the efficiency of the entire network. Software-based, subscriber bandwidth management tools such as the Shaper, will allow administrators to scale effortlessly their service and network offerings, offering granularity of control right down to the individual IP address.

This product is a “point control” bandwidth management device. We will carefully avoid using the terms QoS (Quality of Service), SLA (Service Level Agreement) and “end-to-end control”, because they do not apply, although are often used. The Shaper monitors and controls bandwidth by being interposed between IP hosts on a network. Its host and topology discovery features, while limited only by the TCP/IP horizon, are only necessary so that the device can detect and manage data flows between host pairs and are not used to apply end-to-end controls. QOS is properly a very specific term that includes, but is not limited to, bandwidth control or traffic shaping. In a similar manner, SLA can include bandwidth allocation provisions, but that is only one item in a very long list. In sum, Dyband is a niche product that manages the bandwidth passing through it and does some limited client administration, related to applying rate policies to IP hosts. This document will discuss how the Dyband complements Cisco’s Service Provider offerings, by filling a niche that Cisco’s current products do not cover.

How the Dyband Shaper Works:

The Dyband Shaper is a software-based, bandwidth management device for IP subscriber or client networks. It features an extremely flexible, programmable queuing mechanism that enables the service provider to provision and enforce an unlimited number of service levels. The Shaper enables the administrator to guarantee the precise allocation of bandwidth to subscribers, in both normal and congested conditions, while keeping packet discards to an absolute minimum. This latter feature, mostly attributable to a per-Shaper queue depth of as much as 10,000 packets, distinguishes the Shaper from most other programmable queue managers, in that it minimizes packet discards under congested conditions. Anecdotally, in head-to-head field trials conducted by prospective customers, the Shaper has been shown to eliminate packet loss that competitive devices exacerbated.

The Shaper is an in-band network device that queues the IP traffic through itself and regulates bandwidth allocation by applying a priority-weighted, fair queuing algorithm. In essence, the Shaper's process is an analog of the IOS traffic-shaping schemes, typified by Generic Traffic Shaping (GTS), except that the "weight" in the Weighted Fair Queue (WFQ) is derived from a combination of the host (typically source) IP and a user-supplied priority level. Cisco's Weighted Fair-Queuing (WFQ) mechanisms classify and weight traffic according to type parameters, such as TCP Port Number or the Protocol field in the IP header. If necessary, IOS traffic shaping can also use Access Control List (ACL) mechanisms to differentiate traffic flows by host IP or MAC addresses, but ACLs tend to be resource intensive as well as difficult to administer, when large numbers of objects are involved. If the bandwidth allocation were to remain an embedded function of the router or switch, dynamic bandwidth management for several hundred subscribers would quickly overwhelm the typical packet switch.

In subscriber-centric corporate networks, using the subscriber's host address as the primary bandwidth-allocation criterion is a logical necessity. After all, this is precisely how the service is provisioned. Today, the standard Systems Administrator's response to congestion is not to constrain the subscribers who overstep their rate limits, but to restrict the bandwidth available to all subscribers, for traffic types that encourage high bandwidth consumption. While this approach alleviates overall congestion, it does not resolve the root cause of the problem, which is the client who exceeds his maximum rate. It also unfairly penalizes the client who stays within his bandwidth limits, but is transferring a data type that the corporation has determined to "cause network congestion". The corporation's contract with the client defines service in terms of rate limits, without mention of traffic type. Bandwidth consumption should therefore be controlled in that manner: Keep each user within his contracted or permitted limits and, in congested conditions, allocate the available bandwidth equitably, with allowance made for prioritization based on added-cost service guarantees or priorities such as educational administrative traffic over residential traffic. That is exactly what The Dyband Shaper does.

Packet loss is avoided by the Shaper's deep packet queues, which typically will allow the TCP "sliding window", rate control mechanism to constrict the data flow, without triggering packet loss and the subsequent performance sapping retry mechanism. The Shaper's 10-millisecond sampling interval also adds to its "packet loss resistance" and allows the device to scale well in heavily congested or over-subscribed networks. This near-instantaneous adaptability, especially in high-load conditions, continues to be one of Dyband's major selling points.

The CMon is a Windows application that provides real-time access to the Shaper's network monitoring functions, as well as acting as the subscriber policy manager. CMon displays the IP topology of the network, which the Shaper has auto-discovered in order to perform its functions. The Shaper actually has two object discovery processes: Host discovery, which allows for name resolution by DNS or LDAP and tracks subscribers in dynamically addressed networks (specifically DHCP and RADIUS) and topology discovery, which maps the hosts for CMon to display. The topology discovery mechanism is ICMP-based and therefore incurs very little network overhead. Similarly, host discovery and the real-time bandwidth consumption monitor, which read from the queued packets, do not add any latency beyond the Shaper's own processing overhead, nominally 10 to 15 ms. The CMon is also the administrative station for the bandwidth allocation policies, which are unlimited and can be applied to individual IP objects or groups of such objects. The CMon displays are unique and provide the single most effective demonstration tool for the entire product.

Dyband has two other main components, Archiver and Miner. Archiver collects usage statistics from the Shaper per IP host, by user-specified intervals and stores them in a SQL database (Oracle, MS-SQL or any database to which an ODBC connection can be made). Miner is a SQL query and reporting tool, which includes a selection of canned reports. They give the corporation the documented history to proactively offer the high-use subscriber a higher service level, or to justify the rate-limitation when he inevitably complains. Archiver/Miner also enable usage-based billing or tracking, which provides an opportunity to bill individual departments or users. Dyband's per-subscriber granularity of both controls and statistics enables the corporation to offer an unlimited variety of differentiated subscriber service tiers, all of which can be guaranteed. As long as the corporation stays within the limits of reality (e.g. a single T1 will not support 10,000 subscribers), it will be able to maximize the usage of its expensive WAN connections. Oversubscription of the Internet-access pipes, already a fact of life for enterprises, can be tuned within extremely fine limits.

In its current iteration, Release 2.1, the Shaper only works in IP networks, on Ethernet links up to and including Gigabit Ethernet (155Mb/s or OC-3). Shaper R.2.1 uses only host-based controls (i.e. it allocates bandwidth according to IP host address), which limits its utility for ASPs and other NSPs who provide more than just tiered bandwidth. However, traffic class controls are easily implemented, given customer demand and will probably be included in the next release.

[*A note on terminology: Throughout this document, we distinguish between traffic shaping by "traffic class" and by "host address". The latter term, host address, is self-explanatory and will mean IP host address, unless otherwise noted. "Traffic class" refers to any criterion other than host address, by which the managed traffic is typed and prioritized. In other Dyband documents, the reader may find the terms "Layer 3" and "Layer 4" controls, which we have now eliminated from this document. In Dyband jargon, "Layer 3" (of the OSI RM) refers to IP host address controls and "Layer 4" refers to any other bandwidth management control. The "Layer 4" appellation is accurate when discussing TCP Port Number, but not when applied to, for example, the TOS field in the IP packet header. For this reason, we used the more awkward "traffic class" terminology.*]

Cisco Traffic-Shaping vis-à-vis Dyband Traffic-Shaping:

Cisco provides its customers with several ways to manage bandwidth, both within IOS and in external systems. The Dyband Shaper should be one of those external devices. It is a network device that provides a comprehensive, subscriber-oriented set of features for managing bandwidth on IP networks. The Shaper enhances the customer's bandwidth control, subscriber configuration and monitoring capabilities, offloading those resource intensive tasks from the packet-switching devices.

[NOTE: *Cisco's IOS family provides a wide range of bandwidth management mechanisms, such as GTS, that classify packets by class-of-service (or priority level) and then uses a queue/discard technique to regulate the aggregate traffic flow across an interface. The class of- service is based on policies determined by the ISP or enterprise, and may require significant per-packet processing overhead, depending upon the ISPs subscriber or enterprise client demands. Congestion, plus the financially driven necessity to oversubscribe purchased network pipes, adds to the complexities of these policies. This places severe loads on the CPU and memory of the IOS device applying the policies, which will, in severe conditions, affect packet-switching performance. If those bandwidth allocation policies include per-host constraints, the ACL storage and processing requirements will rapidly overwhelm the available resources*.]

Cisco's IOS controls IP traffic through GTS (Generic Traffic Shaping), which applies Weighted Fair Queue algorithms by parsing the IP header for Layer 4 parameters. Under congested conditions, there are a number of packet discard schemes, such as WRED (Weighted Random Early Detect), that work quite well. The fundamental limitation with IOS-based traffic shaping and enforcement is that it becomes resource-intensive quite quickly. If the user decides to use GTS to control traffic on a per-subscriber basis, the only mechanism is the Access Control List (ACL), which becomes problematic with hundreds, much less thousands, of entries. For a small ISP with several hundred subscribers, or a business with several hundred users, using a Cisco 3600 to access the Worldwide Web, the resultant ACL processing would drive the router to thrashing long before actual congestion began.

Cable MSOs using Cisco's 7200-series CMTS's, often point to DOCSIS as a "traffic shaping" mechanism. DOCSIS only provides rate caps and these are often violated by casual users on underutilized network pipes. It is not designed as a bandwidth allocation service and provides no minimum bandwidth or equitable bandwidth distribution functionality. Our empirical experience with cable MSOs is that they are favorably impressed with both the network visibility and the level of guaranteed bandwidth allocation that the Shaper offers. Cisco has two ancillary products that provide rate policy configuration, along with other capabilities: QPM (QOS Policy Manager) and QDM (QOS Device Manager). These are essentially device administration tools that provide an easy way to configure IOS devices from a central point. While effective, they are not coupled with a topology mapping tool and, as they generate IOS command scripts, are bound by IOS rules and do not relieve the resource problems discussed previously.

In contrast, the CMon incorporates dynamic, real-time IP host/topology discovery and applies rate policies to objects or groups of objects, in that topology. CMon incorporates the concept of a Management Point: An object, either on the topology or user-created, which is specifically monitored and managed via a rate policy. The MP can be anywhere in the logical IP hierarchy, such as an individual host, a subnet or a group of non-contiguous subnets. The MP is not, however, restricted by IP logic: A group of disparate IP hosts can be aggregated into a Management Point. As rate policies can be "inherited" down from an MP, administration is simplified. Rate policies are administered separately from the objects to which they are applied and allow specification of minimum, maximum and burst rates under normal and congested conditions. When applied to a group, the rate policy effectively defines a partition on a network pipe. This rule flexibility is not available under any IOS-based mechanism. The two traffic-shaping schema can complement each other. Traffic type controls, such as classification by TCP Port Number, are easily and efficiently applied at a router interface within IOS. In ISPs or in enterprises, traffic shaping at the network distribution layer, can be done on IP host address, downstream of the traffic type controls on a router interface. The two do not compete.

Solving the Subscriber Bandwidth Allocation Problem:

Internet Service Providers need to precisely allocate bandwidth at the distribution/edge layer of their network. They sell bandwidth and, as such, tend to have very little interest in how their subscribers use that bandwidth. In the continuing effort to distinguish themselves, ISPs are offering more service plans to their subscribers. In the continuing effort to ensure profitability, they also continue to over-subscribe their web access pipes. Under these pressures, they need a way to precisely allocate bandwidth, guarantee that allocation and manage their network pipes.

The expensive solution is to migrate to purpose-built aggregator products, such as Redback's highly successful line of edge concentrators. Typically, this class of product incorporates high speed packet switches, displacing the existing infrastructure devices, at least 80% of which are Cisco products. A cheaper and more scalable solution, especially for Tier 3 providers, would be to insert a programmable, software-based traffic management device, of which the Dyband is the leading example.

The overwhelming majority of the packet-switching devices on the Internet today are Cisco routers and switches. Deploying the Dyband product within this existing infrastructure, would allow Internet Service Providers to enhance the subscriber bandwidth control and monitoring capabilities of their distribution infrastructure, without re-engineering and re-equipping. Cisco's IOS-based traffic management mechanisms do not offer the constraint-free flexibility that the Shaper has, nor do they have the various monitoring, tracking and policy administration features that Dyband offers. IOS devices are primarily packet switches and ancillary functions as security and subscriber bandwidth allocation, are better handled by firewalls and discrete bandwidth management devices, respectively.

Common Approach:

There are two approaches used for IP traffic-shaping today: packet queuing and TCP Rate Control. Queuing is a generic technique that can be applied to any packetized network traffic and always includes a "packet discard" mechanism. It is important to remember that all packet-queuing techniques for TCP/IP bandwidth control, take advantage of TCP's retry and rate control mechanisms. Packet queuing is usually weighted in some way and is most often based on equitable allocation of the managed bandwidth, modified by those weights. The key differences between different queuing implementations lie in their resistance to packet loss and in how they are weighted. As both Cisco IOS and the Dyband Shaper use weighted fair queuing, we will not discuss the merits of traffic-shaping by manipulating TCP Rate Control alone, an approach used by some competing products.

There are actually two layers of traffic shaping that concern the ISP:

- Per-subscriber, based on host IP/MAC address
- Aggregate, based on traffic type and/or subnet

Per-subscriber rate control is critical to ISPs, as this is the basis on which they write service contracts, fulfill and bill. That granularity of control and data-collection is essential in a subscriber rate-management device. Aggregate control is sometimes important, even essential (ASPs would be a classic example) to the operation, but neither is intrinsically superior. Dyband's empirical experience has been that the Tier 2 and Tier 3 ISPs are very concerned about per-subscriber traffic-shaping and monitoring and actually do very little, if any, traffic shaping based on aggregate criteria.

IOS-based rate control typically uses Class-Based Weighted Fair Queuing (CBWFQ), which works very well to control aggregate traffic flows. In IP networks, Random Early Detection (RED) or Weighted RED (WRED) mechanisms will handle any necessary discards until TCP Rate Control can adjust the data rates on the individual flows down, to match the specified aggregate rate for that service class. This only solves one part of the ISP bandwidth management problem.

Internet Service Providers sell bandwidth to subscribers, typically within narrowly defined bounds as defined by maximum rate, minimum rate and burst rate. Aggregate schemes such as GTS with

CBWFQ, do not address the individual subscriber's rate control problem. Within IOS, individual host data rates can be controlled via ACLs, but this becomes inefficient very quickly, especially when even a small ISP will have several hundred subscribers. Even in ATM networks, Cisco's COS (Coarse Grained Quality of Service) only provides control down to the Virtual Circuit (VC) level. Per-subscriber bandwidth control can only be realistically applied with a discrete device such as the Dyband Shaper.

By providing deep packet queues (10,000 per Shaper) and sampling every 10 ms., the Dyband Shaper provides almost-instantaneous rate restriction and avoids packet loss. It provides the per-subscriber control that an Internet Service Provider needs, in order to guarantee service levels under all traffic conditions. Moreover, by operating at the host level, the Shaper provides the necessary monitoring and consumption-tracking granularity for the ISP to document individual subscribers' usage. This can be used to justify rate-control measures, for overaggressive subscribers or as the basis for usage-based billing.

While both the Shaper and Cisco IOS-based packet switches do "shape traffic" with similar mechanisms, they differ in several important ways. Primarily, the Dyband product is executed in software, on several generic hardware platforms, and is a standalone device. As such, the bandwidth management process does not compete for hardware resources (mainly CPU cycles and memory), which is the major limiting factor for IOS traffic-shaping. Mostly because of the resource constraints, IOS traffic shaping is unable to deal with hundreds, much less thousands, of subscribers without seriously degrading packet switching performance. Cisco packet switches are, however, able to classify traffic on an aggregate basis with minimal impact on throughput, even in the near-wirespeed devices. ISPs need both per-subscriber bandwidth management and high performance packet switching in their network infrastructure, but not necessarily in the same device. The Dyband Shaper relieves the packet switches of the bandwidth management load, while massively enhancing that capability, leaving their resources free to route packets at rated speed.

[*NOTE: The Dyband Shaper is an IP-only, edge device. It therefore is not applicable in non-IP networks, such as SNA over Frame Relay, which are common in Large Enterprise environments. It is appropriate in any network that includes Internet access, as that is by definition, a TCP/IP environment.*]

Differentiating Dyband and Cisco IOS Traffic Shaping:

Dyband and Cisco IOS both "shape traffic", or manage bandwidth, on TCP/IP networks. IOS will shape traffic on non-IP networks as well, but the Dyband product is specifically for TCP/IP networks. As a result, this discussion will be confined to bandwidth management on TCP/IP networks.

The most obvious difference is that the Dyband Shaper is a discrete network device, while IP traffic shaping is an embedded function of IOS, which is the "operating system" for Cisco's packet switching devices. The Shaper, being a dedicated bandwidth management device, does not have the resource constraints that IOS traffic shaping mechanisms will inevitably incur. This enables the Shaper to offer a much richer feature set, as well as adding monitoring functions that a switch or router cannot provide.

The major points of difference are:

- The Dyband Shaper manages traffic between IP hosts. IOS traffic shaping manages traffic based on “traffic class” differentiators, such as Protocol or Type of Service from the IP header or the TCP Port Number. Using ACLs, IOS can also manage traffic by host address, but this is a severely resource-intensive exercise and is not practical for hundreds of managed IP objects.
- IOS also shapes non-TCP/IP traffic, but that is outside the scope of this document.
- The Shaper manages both inbound and outbound (relative to itself) traffic, while IOS traffic shaping can only be applied to packets outbound from an interface.
- By using relatively deep packet queues, the Shaper eliminates or minimizes packet loss under congested conditions. Being resource-constrained, IOS traffic shaping does not have this level of resistance to packet loss.
- The Shaper detects and adjusts for congested conditions. IOS traffic shaping has no such functionality.
- Rate policy administration and consumption monitoring, per IP host, are integrated into the Dyband product set. These functions are not within IOS and are typically handled by external systems, if they are handled at all.

In TCP/IP networks, the two mechanisms do not directly compete. Dyband adds per-host manageability into networks where Cisco IOS could only offer aggregate-flow traffic shaping and does so at a very reasonable cost. It therefore adds functionality and scalability to any enterprise or ISP or network where Cisco packet switches form the basis of the network infrastructure and where delivery of guaranteed bandwidth to subscribers or the usage of bandwidth by clients is a concern. Most of Dyband’s competitors duplicate IOS’s traffic class controls and only subdivide traffic on host addresses as a second control level. They compete with Cisco IOS in the Enterprise market, hence their focus on managing IP traffic by type, and they compete again in the NSP space. Dyband does not.

Market Positioning Considerations:

In its current iteration, Dyband is designed for Internet Service Providers and Enterprise customers, which are primarily client- or subscriber-based, TCP/IP environments. It manages traffic based on host IP address (layer 3 of the OSI RM).

As mentioned previously, ATM at the distribution layer effectively precludes the Shaper, although networks with ATM core layers and Ethernet at the edge, which are common in some larger ISPs, could still deploy Dyband advantageously. ATM networks pose somewhat of a dilemma for Dyband. Aside from the huge technical hurdle in adapting the Shaper to handle ATM interfaces, ATM-based ISPs do offer an opportunity. ATM controls bandwidth very tightly and globally, down to the individual Virtual Channel (VC). The trouble is, allocating one VC to each subscriber is not realistic so, although the ATM network can guarantee aggregate bandwidth allocation for all the subscribers in a given VC, it cannot do so on a per-subscriber level. Therefore, deploying the Dyband Shaper near to the edge of a ISPs ATM network, just “inside” of the subscriber access switching points, would add needed capabilities to that network. All Dyband needs is an Ethernet insertion point.

Dyband is a bandwidth-management “add-on” device in any IP network that needs host-level (or per-subscriber) bandwidth control, monitoring and tracking. It provides bandwidth management capabilities that Cisco’s non-ATM devices do not currently offer and is therefore a valuable companion device in any ISP environment that does not use ATM as the subscriber-side transport, at the access POPs.

Dyband has been successfully deployed at headend facilities for Cable MSOs, sitting between the Internet gateway router and the CMTS. They are also used by wireless ISPs, who typically have asymmetrical networks, with complete effectiveness. Although the Shaper is primarily an Ethernet device, it was successfully tested with Lucent SONET NICs for a potential client. Dyband works well in DSL, wireless and wireline environments. It is appropriate in any IP network that is not ATM to the edge and where there is a need to manage bandwidth on a per-subscriber basis.

Some of the better-funded ISPs are buying carrier-level equipment, such as Redback's SMS and SmartEdge lines, which have extremely capable subscriber/bandwidth management features. As self-provisioning edge concentrators with integrated subscriber and rate management functions, these products are very complete. They are also very expensive. By adding a Dyband Shaper to its access POP, a Tier 2 or 3 ISP could continue to use its existing network infrastructure, while adding bandwidth management and monitoring that is at least as good as the Redback SMS equivalent, at a fraction of the cost. Although Dyband has not been used in this way thus far, it could be deployed along with traditional DSLAM and router configurations, to mitigate the need for a full-function aggregator/subscriber manager, such as the Redback SMS. Using a combination of Cisco gear, it is possible to approximate the functionality of a Redback SMS with Cisco equipment, with the exception of the bandwidth management and rate policy administration functions. Dyband provides that last piece.

As a store-and-forward device, the Shaper is naturally capable of decoding and acting upon, other fields in the packet header than the host address. In response to customer demand, a limited subset of traffic class controls will be available in the next release of the Dyband Shaper, although this will probably exact a small performance penalty. The original design decision to use host-address controls still provides the Dyband product with an edge in the burgeoning ISP market, but there are some emerging service areas, such as VoIP, where the traffic class functionality is essential. At this intersection point, both IOS and Dyband traffic shaping technologies are symbiotic.

The term "traffic-shaping" connotes Application Layer controls in today's techno-speak. Partly because of resource constraints and partly because of Enterprise-market demand, Cisco's various IOS traffic-shaping mechanisms are most efficient as aggregate (per interface), traffic class controls. Dyband adds the IP-host-level controllability that all subscriber based NSPs require, without imposing any performance overhead on the packet-switching devices. A customer adding the Dyband product to his Cisco network infrastructure extends traffic shaping into subscriber level bandwidth control.

Conclusion:

In any TCP/IP network where allocating bandwidth to specific hosts is an over-riding concern, Dyband will enhance Cisco's ability to fulfill the customer's needs, as regards bandwidth and subscriber management. The Dyband technology complements Cisco's IOS-embedded traffic shaping mechanisms, by off-loading the most resource-intensive processes from the packet switching devices and by adding rate policy and subscriber management functions. In some instances, notably VoIP scenarios, the two mechanisms interlock neatly, to provide a solution that is greater than the sum of its parts.

Dyband will enhance Cisco's bandwidth management capabilities, by providing tight, dynamic subscriber-level control and monitoring. This complements Cisco's IOS bandwidth management in the area where it has limitations: Managing traffic for large numbers of IP hosts. Where IOS traffic shaping has been and remains effective is in allocating bandwidth in aggregate, according to traffic class. Dyband adds the capabilities of per-IP-host bandwidth allocation and guaranteed rate control, as well as consumption monitoring and logging. These are compelling features for business; utilizing Dyband in a Cisco environment is a win-win scenario. Dyband provides unique bandwidth and subscriber management functionality that Cisco does not currently offer, and Dyband's capabilities will provide the customer with a cost-effective way to preserve his incumbent Cisco infrastructure and enhance his service offerings. When selling into Internet startups, Dyband will enhance Cisco's offering with bandwidth control and subscriber management capabilities that every business needs, but which Cisco does not currently offer. A Dyband partnership will nurture existing customers and attract new ones. Those are the two best reasons for any business partnership.

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