

# LAN Switching

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LAN switching is a technology that promises to increase the efficiency of local area networks and solve the current bandwidth problems. This paper covers switch features, switching architectures, protocol support and management functions provided in switches and provides some guidelines for switch shopping. It also touches on how switches can be used to implement virtual LANs and ease management functions.

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# 1. Introduction

Local Area Network (LAN) technology has made a significant impact on almost every industry. Operations of these industries depend on computers and networking. The data is stored on computers than on paper, and the dependance on networking is so high that banks, airlines, insurance companies and many government organizations would stop functioning if there were a network failure. Since, the reliance on networks is so high and the network traffic is increasing, we have to address some of the bandwidth problems this has caused and find ways to tackle them.

## 1.1 Bandwidth Problem in LANs

Local Area Networks in many organizations have to deal with increased bandwidth demands. More and more users are being added to the existing LANs. If this was the only problem, it could be solved by upgrading the backbone that connects various LANs. Bridges and routers can be used to keep the number of users per LAN at an optimal number. However with increase in the speed of workstation the bandwidth requirement of each machine has grown more that five times in the last few years. Coupled with bandwidth hungry multimedia applications, and unmanaged and bursty traffic this problem is further aggravated. [[Anixter white paper](#)]

With the increasing use of client-server architecture in which most of the software is stored in the server, the traffic from workstations to server has increased. Further, the use of a large number of GUI applications means more pictures and graphics files need to be transferred to the workstations. This is another cause of increased traffic per workstation.

LAN switching is a fast growing market, with virtually every network vendor marketing its products.

Besides LAN switches, switching routers, switching hubs are also sold. Different vendors add new features to their products to keep them competitive. At present, one can get switches that link same as well as different LAN topologies.

## 1.2 Possible Solutions

The conventional approach would be to install a faster network technology, for example replacing Ethernet with Asynchronous Transfer Mode (ATM), Fiber Distributed Data Interface (FDDI) or fast Ethernet. Although these are great technologies, such a move is expensive, needs new equipment, staff training and the network downtime also takes its toll. Another approach would be to segment the network into smaller parts using bridges and routers. This too is expensive, although not as much as complete migration to new networking technology and would only work if the traffic between segments is low. Otherwise, bridges and routers would act as network bottlenecks and frame loss may occur.

LAN switching is considered to be a solution to this problem and has been adopted by many organizations. Besides making more bandwidth available, it can also form an intermediate step in moving to faster networks such as ATM.

## 1.3 How can LAN Switching help?

The reason it works is simple. Ethernet, token ring and FDDI all use shared media. Conventional Ethernet is bridged or routed. A 100 Mbps Ethernet will have to divide its bandwidth over a number of users because of shared access. However with a switched network one can connect each port directly so bandwidth is shared only among a number of users in a workgroup (connected to the ports). Since there is reduced media sharing more bandwidth is available. Switches can also maintain multiple connections at one point.

## 1.4 Bridges and Routers

Conventional Ethernet uses bridges and hubs that work in a half duplex mode. Using the Carrier Sense Medium Access/Collision Detection (CSMA/CD) protocol the sender senses the channel before transmitting. Collisions can occur if stations start transmitting at the same time. This causes delay and increase in transmission time. An increase in transmission time may also result as each station has to wait until transmission by others is complete.

A bridge divides the network into two collision domains thus reducing congestion as only frames that need to be forwarded are sent. Routers divide network into different broadcast domains and help similarly. Problems range from time to gain access to the media to latency in bridges and routers. Also, higher bus length implies more propagation delay. This architecture is thus not scalable. In contrast, switches have a much lower latency and have a scalable architecture. More features are listed in the next section[Christensen, 1995]

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## 2. Switch Features

Switches normally have higher port counts than bridges and divide network into several dedicated channels parallel to each other. These multiple independent data paths increase the throughput capacity of a switch. There is no contention to gain access and LAN switch architecture is scalable. Another advantage of switches is that most of them are self configuring, minimizing network downtime, although ways for manual configuration are also available.

If a segment is attached to a port of a switch then CSMA/CD is used for media access in that segment. However, if the port has only one station attached then there is no need for any media access protocol. The basic operation of a switch is like a multiport bridge. The source and destination Medium Access Control (MAC) address of incoming frame is looked up and if the frame is to be forwarded, it is sent to the destination port. Although this is mostly what all switches do, there are a variety of features that distinguish them, like the following.

### 2.1 Full Duplex

Full duplex mode of Ethernet allows simultaneous flow of traffic from one station to another without collision. So, Ethernet in full duplex mode doesn't require collision detection when only one port station is attached to each port. There is no contention between stations to transmit over a medium, and a station can transmit whenever a frame is queued in the adapter. The station can also receive at the same time. This has a potential to double the performance of the server. The effective bandwidth is equal to the number of switched ports times the bit rate on medium/2 for half duplex and for full duplex equal to number of switched ports times the bit rate on medium. One catch to this is, that while a client can send as well as receive the frames at the same time, at peak loads server might be overburdened. This may lead to frame loss and eventual loss of connection to the server. To avoid such a situation, flow control at the client level may be used.

Another big advantage of full duplex, is that since there cannot be a collision in full duplex, there is no MAC layer limitation on the distance, eg 2500 m for Ethernet. One can have a 100 km Ethernet using a single mode fiber. The limitation now is at physical layer.

Thus, media speed rates can be sustained depending upon the station and the switch to which it is attached. The user is unaware of full duplex operation, and no new software applications are needed for this enhancement.

### 2.2 Flow Control

Flow control is necessary when the destination port is receiving more traffic than it can handle. Since the buffers are only meant for absorbing peaks traffic, with excessive load frames may be dropped. It is a costly operation as delay is of the order of seconds for each dropped frame.

Traditional networks do not have a layer 2 flow control mechanism, and rely mainly on higher layers for this. Switches come with various flow control strategies depending on the vendors. Some switches upon finding that the destination port is overloaded will send jam message to the sender. Since the decoding of MAC address is fast and a switch can, in very little time, respond with a jam message, collision or packet

loss can be avoided. To the sender, jam packet is like a virtual collision, so it will wait a random time before retransmitting. This strategy works as only those frames that go to the overloaded destination port are jammed and not the others.

## 2.3 Static and Dynamic Switching

- **Static Switching**

The functionality is similar to that of a hub as the traffic goes to all other ports in the group. Since individual hubs are cheaper, they are normally preferred.

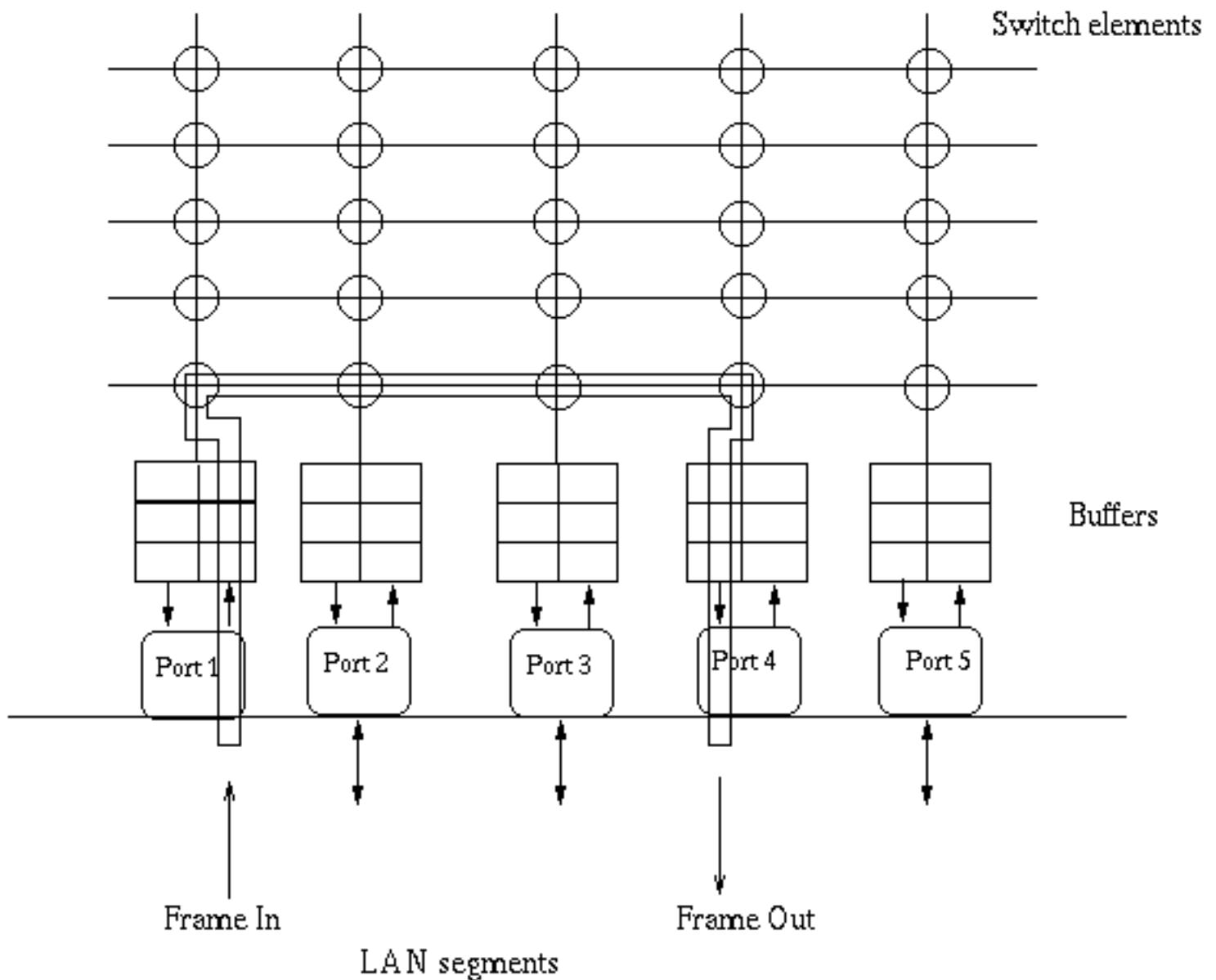
- **Dynamic Switching**

These switches learn on which port a station is attached by studying the frames that station transmits. Once learned, the frames are transmitted only to the destination station, saving the bandwidth of other stations. Stations are relearned everytime, so any change of station from one port to another is automatically reconfigured.

## 2.4 Cut-Through Versus Store-and-Forward Switching

### Cut-through switching

Marked by low latency, these switches begin transmission of the frame to the destination port even before the whole frame is received. Thus frame latency is about 1/20th of that in store-and-forward switches (explained later). Cut-through switches with runt (collision fragments) detection will store the frame in the buffer and begin transmission as soon as the possibility of runt is eliminated and it can grab the outgoing channel. Filtering of runts is important as they seriously waste the bandwidth of the network. The delay in these switches is about 60 microseconds. Compare this with store-and-forward switches where every frame is buffered (delay: 0.8 microsecond per byte). The delay thus for 1500 byte frame is 1200 microsecond. No Cyclic Redundancy Check (CRC) verification is done in these switches. Figure 1 shows a frame being forwarded from port 1 to port 4 without being stored in buffer.



**Figure 1.:** Cut through Switching

### Store-and-forward switching

This type of switches receive whole of the frame before forwarding it. While the the frame is being received, processing is done. Upon complete arrival of the frame, CRC is verified and the frame is directly forwarded to the output port. Even though there are some disadvantages of store-and-forward switches, in certain cases they are essential. For example when we have a slow port transmitting to a fast port. The frame must be buffered and transmitted only when it is completely received. Another advantage would be in high traffic conditions, when the frames have to be buffered since the output port may be busy. As traffic increases the chances of a certain output port being busy obviously increase, so even cut-through switches may need to buffer the frames. Thus, in some cases store-and-forward switching has its obvious advantage.

## 2.5 Address Resolution

To allow forwarding and filtering of packets at wire speed, LAN switches should be able to decode MAC addresses very quickly. Since Central Processing Unit (CPU) based lookups are expensive, hardware solutions may be used. Switches maintain address tables just like transparent bridges. They learn the addresses of their neighbors, and when a frame is to be forwarded, they first look up the address table and broadcast only if no entry corresponding to that destination is found. Stations that have not transmitted recently are aged out. This way a small address table can be maintained and the switch can relearn if a station starts transmitting again.

## 2.6 Multiple LAN Technologies

Switches can support ports having single LAN technology or a multiple of them. But according to [Buyer's Guide: Network World, June'96], no vendor supported all six LAN technologies namely, Ethernet, 100Base-T, FDDI, token ring, ATM and 100VG-AnyLAN. The reason for this is that

- the vendors don't have the resources for this and
- most mixed LANs don't use more than 2-3 different LAN technologies.

## 2.7 Network Management

This is an important feature, as it allows the network administrator to detect a problem even before it occurs. Most switch vendors provide some kind of network management. Monitoring is mainly through Simple Network Management Protocol (SNMP) or Remote Monitoring (RMON) while diagnostics are mostly proprietary.

RMON is used for real-time performance and error statistics. When implemented in three stages, it consists of:

1. Statistics, History, Event and Alarms as first four groups
2. Hosts, HostTopN, Matrix and Filter as next four groups
  - Hosts group*: Gives statistics stored for all MAC addresses
  - HostTopN*: Gives position of stations based on traffic and error statistics
  - Matrix*: Gives information about who communicates with whom
  - Filter*: Provides user with the ability to select specific packets
3. And finally Capture:
  - It has a significant influence on cost, being the most memory intensive of the three.

Since many vendors offer RMON support or at least promise to do so in near future, it will be a standard feature except in some cheaper switches.

Mirror ports can be used to monitor traffic through other ports. Most of the vendors provide support for this, and others plan to do so in near future. HP, IBM, Ornet and UB designs have designated specific ports for mirroring. When this port is not being used for mirroring, it can be used for other traffic.

## 2.8 Fault Tolerance

Since switches form a major part of the network, their reliability is of utmost importance. Hot swapping for connectivity media, power, uplinks and fans are provided. Redundancy is also a part of fault tolerance. Redundancy in management processor, power, fans and port backup is used by some vendors. Allowing one port to back up another can be very important in critical sections of the network. Since most products use Spanning Tree Algorithm, redundant port is automatically activated once primary port fails. Most high end switches provide at least some fault-tolerance features.

## 2.9 Multilayer Switching

Multilayer switching has been described as the *next architectural generation of LAN switching*. [Communications Week, 1997] Multilayer switches are important for networks using ATM and gigabit Ethernet. Although the definition for multilayer switches is not standardized, they can be described as switches that besides MAC layer routing, have some routing layer functionality like multicast and broadcast containment, some VLAN services, and Packet filtering and firewalling between two VLANs. They may also support Transmission Control Protocol/Internet Protocol (TCP/IP) and Internetwork Packet Exchange (IPX) routing. Many of these switches provide support for frame and cell switching.

One of the most important features would be that it provides gigabit level scaling. This makes it easier and cheaper to upgrade the network in future when the demands on network increases. Using policy based VLAN, support for various classes of service and Quality of Service can be provided. Thus offering features that were once available only in ATM networks.

LAN switching products have gone down in cost in the last couple of years, and the price/performance ratio is favorable. The advantage for a network manager is that it provides better service at a lower cost. Further, at times of network upgrade, less staff need to be retrained, as the network is scalable. According to one of the studies, it was found that network managers were able to spend 30% more time on design and performance-trending activities in a switch based environment. Multilayer switching is increasingly being used in data-center implementations. These switches provide high network capacity along with greater internetworking functionality using the VLAN services.

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## 3. Switch Architecture

Various kinds of switch architectures have been developed. Because of this we need to find a way of determining which is better. In industry, performance to cost ratio is used to determine optimal architecture for a particular application. Switch cost is measured on a per port basis, obtained by dividing the cost of the switch by the number of ports. Switching fabrics use single stage solutions like Time Division Multiplexing (TDM) bus (high speed bus) or space division methods that are multistage (multistage switch array) or meshed (cross-bar). [Christensen, K. J.]

## 3.1 Frame Versus Cell Switching

Traversing of a frame through the fabric of a switch can be using frame switching model, in which the whole frame is sent as such to the destination port, or using cell switching where each frame is broken down into equal sized cells. In cell switching, a frame at the input port is broken into the cells and is reassembled at the output port. In frame switching the time of occupation of the transmission path between the input and output port depends upon the size of the frame. Thus for a 64 byte long frame transmission time would be 51.2 microsecond, and would be as high as 1.21 millisecond for a 1518 byte long frame. That means the latency will depend on the frame size. For cell switching, since a cell is of constant size, the transmission time is the same. So, cell switching performance does not depend on the data traffic, type of data or the number of ports. Currently, frame switching seems to be the general trend among LAN switching vendors and none of these approaches have been proved to be better than other.

## 3.2 Buffering

In the section 2.4 we briefly discussed the importance of buffering. Mostly, the following three types of buffering techniques are used:

1. **Input buffering.** Frames are buffered at each input port. So the incoming frame is stored in the buffer as it is received. This is helpful in situations when more than one station is trying to send to the same output port. The input is buffered and forwarded only when the destination port is free. Input buffering may be used to support broadcast and multicast.

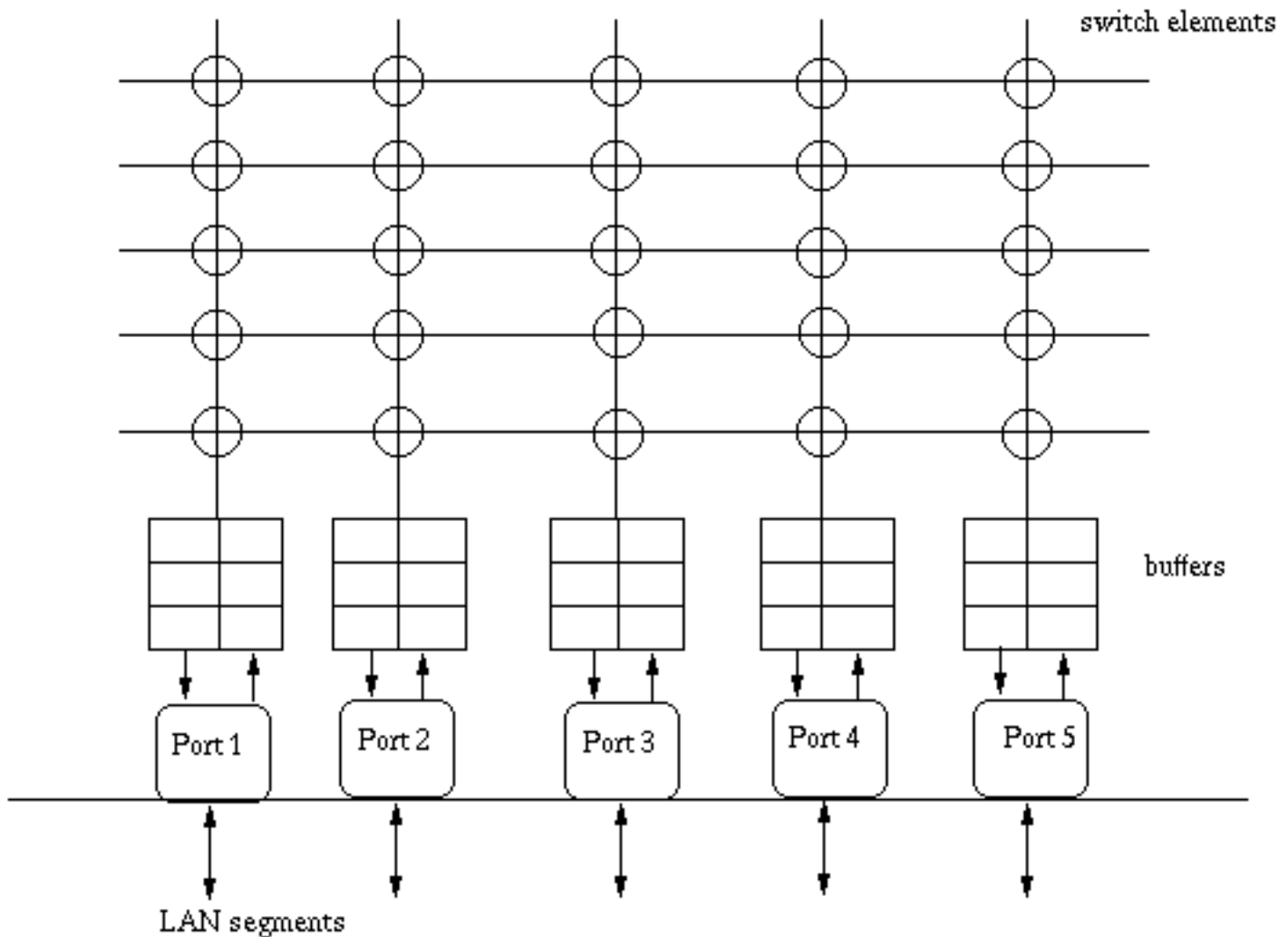
A problem might occur when frames need to be delivered to two different destination ports. If in the input queue, a frame B is waiting behind A whose destination port is extremely busy, B may have to wait even though its destination port is free. This is called *head-of-line* blocking. Some switches can avoid such a problem if the control logic can look into the destination address of the frames in the queue and if destination address is free, forward them bypassing the first frame. Such switches are more efficient.

2. **Output buffering.** This solves the problem of head-of-line blocking as frames received are forwarded to the destination, and buffered in output buffer if the output port is busy. Common buffer pools may be used where multiple output streams may be buffered in a common memory space. Fast memory with multiple access is required in this case. Output buffer is useful when the traffic to a destination port is heavy. Problem might occur when one station is sending heavy load to a destination port, then other stations sending to the same destination port may be denied access. So this is not a fair method.
3. **Path buffering.** Both of the above problems can be avoided with this method as separate buffers exist for each input and output port pair.

## 3.3 Blocking and non-blocking switch architecture

Non-blocking architecture means that frame being forwarded from ports 1 to 5 cannot block the forwarding of another frame from ports 2 to 4. Example. Multistage Banyan and cross-bar architecture (figure 2). In a blocking architecture, internal collisions can occur. The switch may retry internally, and

discard after a certain number of retries. Non-blocking architectures provide a higher internal bandwidth, and are thus more expensive.



**Figure 2.:** Cross-bar switch with 5 ports

### 3.4 RISC Versus ASIC

The following two types of architectures are commonly used.

- **Reduced Instruction Set Computer (RISC):** Hardware design based on RISC CPUs is much cheaper than the customized counterparts that are exclusively designed for switching. RISC processors are widely used and thus available at lower cost. They can forward frames based on Layer 2 (MAC layer) or Layer 3 (Network layer) addresses acting like a bridge and router respectively. Further we can add extra functionality by installing extra software. The only problem is that they are store-and-forward type and thus have higher latency times than switches based on ASIC architecture.
- **Application Specific Integrated Circuit (ASIC):** These processors are customized for a

particular operation and all of the functionality is in the hardware. Although this makes it much faster, we cannot add extra functionality using available software. Such switches will in most cases do cut-through forwarding based on layer 2 (MAC layer) addresses. It creates dedicated paths for each input port and output port traffic channel. So buffering is not essential like in bridges.

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## 4. Switched LAN Topology

High speed interfaces are needed in certain regions of high traffic. These may be at workgroup level or at the backbone level. Following are certain regions where such interfaces may be essential.

- **Workgroup level** Clients working with multimedia or any other bandwidth hungry application will consume lot of bandwidth, so the workgroup should be appropriately segmented to keep the traffic low in that particular LAN segment. Replacing concentrators, repeaters, or hubs in a workgroup with LAN switches can substantially increase the effective transmit bandwidth to each user. Full duplex operation would further enhance the bandwidth availability. Workgroup switches should be provided with high speed ports for connecting to servers.
- **Backbone level** One may need a fast 100Base-TX interface for connection to a server, since most of the traffic from the workstation has to go to the server. Since, this can be a bottleneck, high speed interfaces are essential for achieving good performance. The server is connected to a high speed port to allow it to work at full efficiency. Another region where such an interface might be required is in connections between switches. This may be essential, when a switch connects a group of workstations to a switch with a group of servers. The link acts like a high speed collapsed backbone.

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## 5. Virtual LAN (VLAN)

While bandwidth may be a reason big enough to go for switching, Virtual LAN (VLAN) support may also be attractive. A VLAN is logical grouping of ports into workgroups. With VLAN support network managers can define workgroups independent of underlying network topology.

VLANs are becoming popular because of the flexibility they offer. Users can physically move but stay on the same VLAN. Some other benefits are:

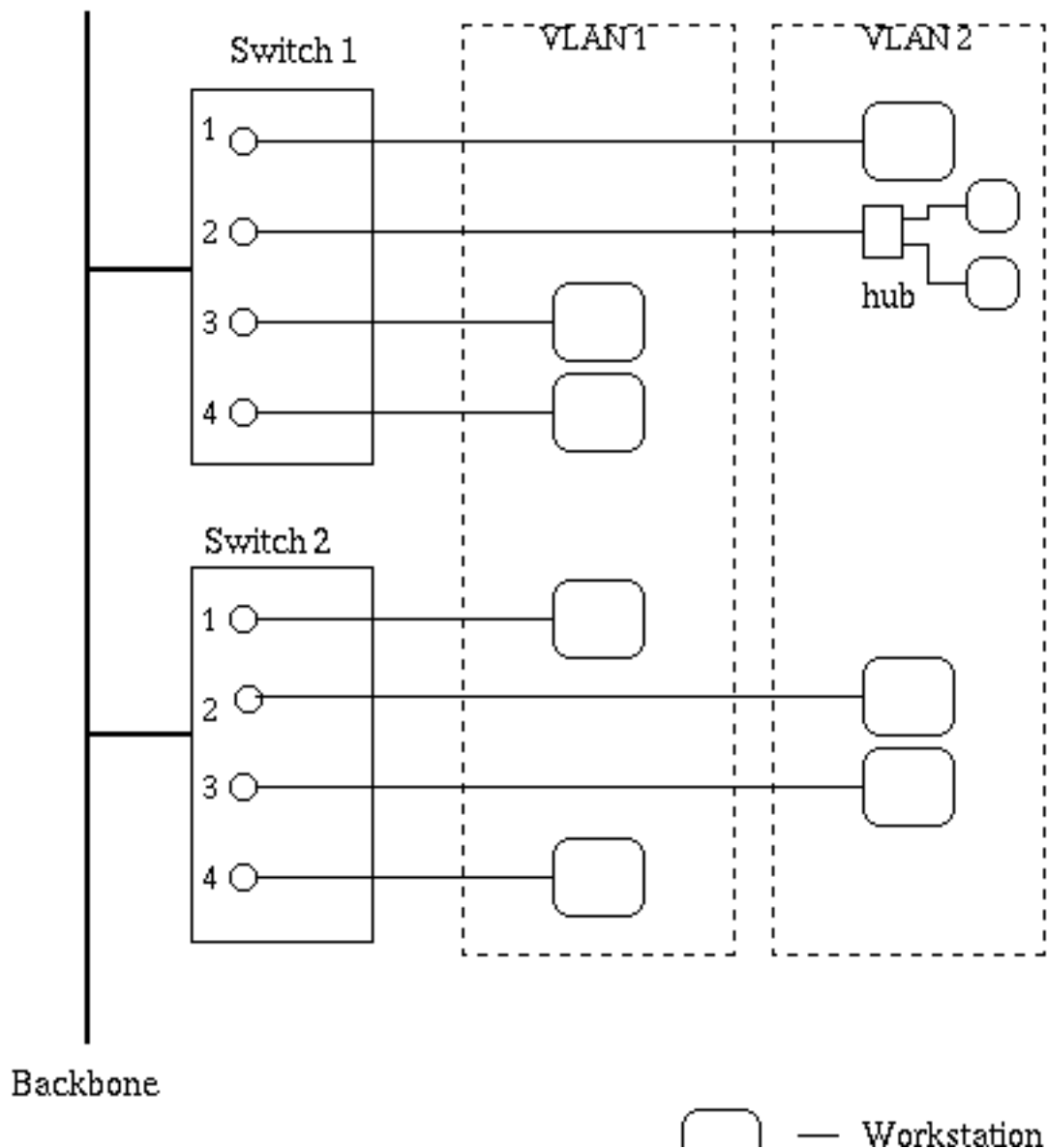
- Moves and changes become easier and less expensive.
- Virtual workgroups. A workgroup model is used where it is assumed that most of the the traffic in a workgroup stays in the same broadcast domain. If the 80/20 rule is maintained, i.e. 80% of the traffic is local and only 20% will need to pass the router, then significant performance improvements can be achieved.
- Broadcast containment using switches. Routers are no more needed for broadcast containment.

The philosophy of "switch if you can and route if you must" is used by most vendors. With networks partitioned into VLANs, broadcast is contained within a VLAN. Broadcast traffic on one port is replicated only for those ports that belong to the same VLAN. Since routing is reduced, we can achieve better performance, reduce latency, and ease administration because routers require a more time consuming configuration process. Further, the cost of switches per port is lower than that of a port in a router. [[The Virtual Technology Report](#)]

- Routers are needed between VLANs and better security concerns can be addressed. If private port switching is implemented in switches, then the traffic on the single user segment would be from its VLAN.

When buying LAN switches, one should be aware what kind of the VLAN support is provided by them. VLAN support can be:

- **Layer 1 VLAN.** Network manager can assign certain ports to a certain VLAN. This way one can include the ports in a VLAN, but if two persons on one segment want to be on different VLANs, that is not possible. Messages are broadcast in a particular segment. This is the simplest kind of VLAN support, and is called port routing or port switching. (Figure 3)





**Figure 3.:** Layer 1 Virtual LAN

- **Layer 2 VLAN.** These are VLANs based on Layer 2 (MAC) layer addresses. The membership of a user depends on their MAC addresses. The main advantage of this is that it provides full user mobility. Another, way of implementation could be VLANs based on MAC protocol type field. This is also called bridge based VLAN.
- **Layer 3 VLAN.** These are VLANs based on layer 3 information. VLAN membership depends on MAC layer protocol field and the subnet field. VLAN configuration is learned by switch, so no manual configuration is required. This is also called Virtual subnet.
- **Higher Layer VLANs.** These are based on different higher layer applications like Multimedia, ftp, etc.
- Some of the switch vendors supporting multilevel, multilayer VLANs are: Network System's Corp., Plaintree Systems and 3Com.

The ideal scenario would be a switch supporting all three levels of VLANs, chosen by the user at will, and configured using a Graphical User Interface.

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## 6. Switch Shopping

Once we have decided to upgrade our network to a switched LAN, we are out shopping for switches. With so many vendors having similar products, it sometimes becomes difficult to decide which switch to buy. Following are some criteria for switch selection and some guidelines to determine whether you are getting your moneys worth. Appendix B gives a list of some leading switches.

### 6.1 Switch Selection

A number of criteria may be used for choosing a switch that will fit your network needs. Some of these are listed below:

- A switch that doesn't drop frames.
- Path buffering switches have better performance.
- For time sensitive applications cut-through switches should be preferred over store-and-forward.
- Switch ports should have RMON capability. (expensive option)
- Latency should be low, but not a very big concern.
- VLAN support should be considered, as it can reduce network management costs.
- Assign dedicated ports for multimedia stations. [[Anixter white paper](#)]

## 6.2 Price

Pricing is complicated and very difficult thing to understand as a lot of factors influence it. However, it is one of the important things one would look at when buying a LAN switch. As discussed earlier, price is generally measured on a per-port basis. Some of the costs are given in section 6.3 (Switch buying guidelines with average costs). For further pricing information see "Comparing LAN Switch Contenders". [Kevin Tolly, Network World, Jul'97]

## 6.3 Switch buying guidelines with average costs

Am I getting a good deal? (Please note that all prices are on a per port basis and are based on a study conducted by Edwin Meir in Sept. 96) [Mier, Network World]

- Average price for Ethernet switches with 12 ports or less is about \$450 or less
- Cost for larger number of ports is higher, as a more powerful central switching engine is needed.
- Choices for token ring switches are limited and are much more expensive. Average price with 12 ports or less is about \$900.
- It is not much more expensive to add 155 Mbps ATM uplink, than to add 100 MBps 100Base-T uplink.
- One can do Ethernet, 100Base-T and FDDI on a single switch with the available products.
- Most of the vendors will offer at least one-year hardware replacement warranty.
- Average latency for a minimum size packet through a cut-through switches is 45.6 microsecond and for store-and-forward switches is 51.5 microsecond. Since the difference is so small, store-and-forward switches are generally preferred. Also, Layland the author of [[Time to Move On?](#)] in his study noticed some unusual problems with cut-through switches.

**Note:** All prices are on a per port basis and are based on a study conducted by Edwin Meir in **Sept. 96** [Mier, Network World]

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## 7. LAN Switching: Not a panacea

Having looked at all the benefits of switched LANs and with the prices of LAN switches falling, one might be tempted to migrate to this new technology. However, this is not a permanent solution and lots of things might need to be considered before making such a decision.

### 7.1 Switch with Caution

Reading vendor's product literature might show that switching is a cure-all for a slow network. But some studies show that if one is not cautious, it may not provide any benefit. LAN switches assume that the core network cannot get saturated as it has extremely high bandwidth. As discussed above most of the switches are provided with buffer that can absorb any temporary burst of traffic. While we need buffers,

they can increase the delay in the switch. That is not good as one of the reasons for moving to switches is low delays. Another problem can be overloading of destination port. If more traffic is directed to a destination port than it can handle, it is going to buffer that. Since buffers are only for temporary bursts, sustained excessive traffic will cause collisions and lead to frame loss. This is worse than collision in shared Ethernet. In shared Ethernet, a station waits a random time before retransmission but here the sending stations keeps transmitting frames thinking the earlier one was received. In such a case higher layer protocols like TCP/IP will time out and take care of it. However this is not the case in datagram protocols for video or voice. Since there is no error recovery, any lost frame is lost forever. This can most likely come up on network applications on switch-to-switch trunks and server trunks, and the chances of collision increase if the destination trunk is slower.

One must not lose hope. Some solutions are available that can almost eliminate these problems. (a) Provide sufficient buffers, although it might increase the delay, frame discards can be avoided. (b) Sender's port should generate a false collision that will force the sender to wait and then retry. Works only with MAC layers having collision detection. Doesn't work for token ring or FDDI. (c) Finally, making the exit link much faster than the data sources can send. Gigabit Ethernet switches can be used as it can supply shared ports with large bandwidth and can prevent collision and frame loss. [Switching's Dark Side]

## 7.2 ATM and Ethernet switching

LAN switching makes the entire bandwidth available to each connected end station. With structured cabling, user can get communication services like voice, video and data communication at workstation. However, when 10 Mbps/100 Mbps is too less for a station, then network manager should think of Asynchronous Transmission Mode (ATM). This technology promises lots of functionality and great flexibility, and has been called as the networking technology of future. LAN Emulation (LANE) is used when ATM technology is used in traditional LANs without any change in applications at the workstations. If the cable structure is ready, migrating to another technology will be less expensive.

A number of issues have slowed migration to ATM. There is going to be a big initial cost for replacing the existing equipment, and Network Interface Cards (NIC) in the current workstations. Some feel that ATM is a new technology, and does not have good management tools. Besides high bandwidth, Quality of Service (QoS) is one of the important things ATM provides that will be essential when dealing with time critical multimedia traffic. For LANs, protocols are being worked out to support multimedia traffic. So, LAN switching is in a way slowing the adoption of ATM.

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## 8. Summary

For bandwidth starved networks, switching offers an opportunity to solve the current problems and keep us prepared for future technologies. It promises higher performance, scalability and improved manageability. Switching is available in Ethernet, FDDI and token ring, and can be used to boost performance. Since the underlying technology is the same, new software is not needed and all this will make the migration cheaper and easier with minimal training requirements.

One must do a thorough analysis of the network before deciding on which technology to use. While choosing a switch, one must emphasize on the features that are going to offer substantial benefits like RMON, mirror ports, varied uplink support, and economical cost. One must realize though, that LAN switching is a quick fix kind of a solution. It can alleviate/eliminate current bandwidth problems, but in long run one must think about alternative technologies like ATM.

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## 9. Appendices

### 9.1 Appendix A: List of Acronyms

- **ASIC** : Application Specific Integrated Circuit
- **ATM** : Asynchronous Transfer Mode
- **CD** : Collision Detection
- **CRC** : Cyclic Redundancy Check
- **CSMA** : Carrier Sense Medium Access
- **FDDI** : Fiber Distributed Data Interface
- **FTP** : File Transfer Protocol
- **GUI** : Graphical User Interface
- **IP** : Internet Protocol
- **IPX** : Internetwork Packet Exchange
- **LAN** : Local Area Network
- **MAC** : Medium Access Control
- **NIC** : Network Interface Card
- **QoS** : Quality of Service
- **RISC** : Reduced Instruction Set Computer
- **RMON** : Remote Monitoring
- **SNMP** : Simple Network Management Protocol
- **TCP** : Transmission Control Protocol
- **VLAN** : Virtual LAN

### 9.2 Appendix B: Buyers' Guide for LAN Switches

Some of the switches rated well by Edwin E. Mier [Network World, Aug. 97] are listed below with some important features obtained from companies web pages and from the above mentioned Network World (referred to below as [NW]) article. [

- **Fore Systems: ES-3810** A switch with exceptional performance. Tested at 1.2 million packet/sec without any loss. Dynamic broadcast and multicast filtering features available. Latency is 61

microseconds per 64-byte packets (10BaseT). Supports VLAN that run on ATM backbone.

- [Cabletron System, Inc.: FN100](#) It can support eight active 100Base-T connections. Can use mixed 10/100Base-T applications, has flow control and broadcast control facilities. Claims wire-speed filtering and forwarding for all Fast Ethernet ports. In testing by [NW] they found some throughput limitations and there may have been some head of line blocking.

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