FORE SYSTEMS

Unicasts, Multicasts and Broadcasts

Part 1: Frame-Based LAN Operation

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LANs as a Shared Medium

A "Private" Conversation

Multicast Addressing

Performance Issues

In this tutorial I'll explain the operation of address recognition on a conventional LAN, and highlight the implications of this mode of operation when we move to a connection-oriented ATM network.

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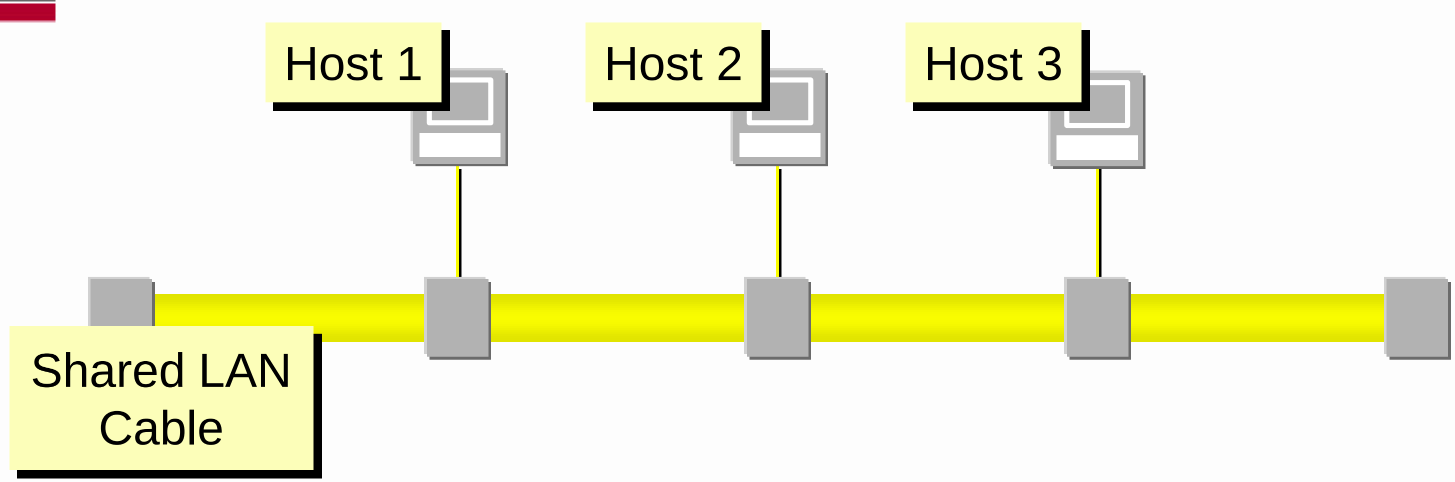
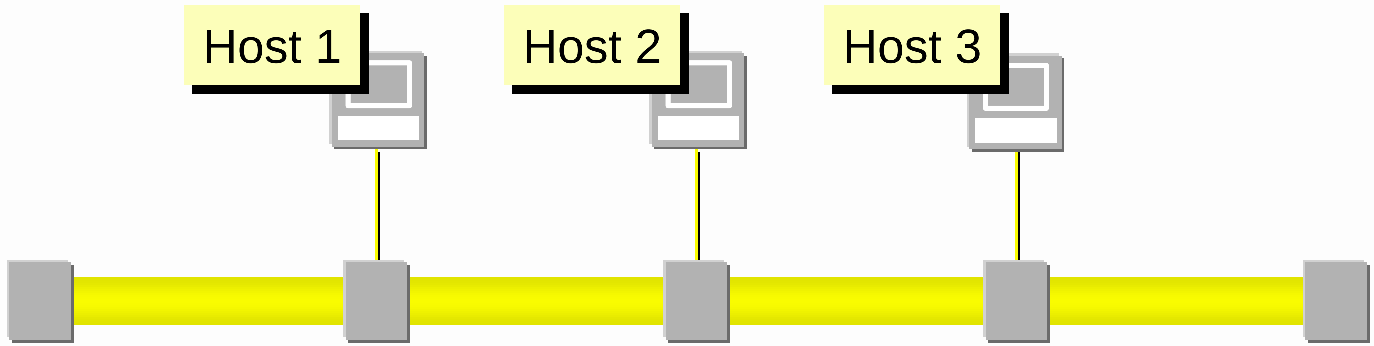
In this section I'll describe the way that shared LAN technologies operate with respect to frame addressing and recognition.

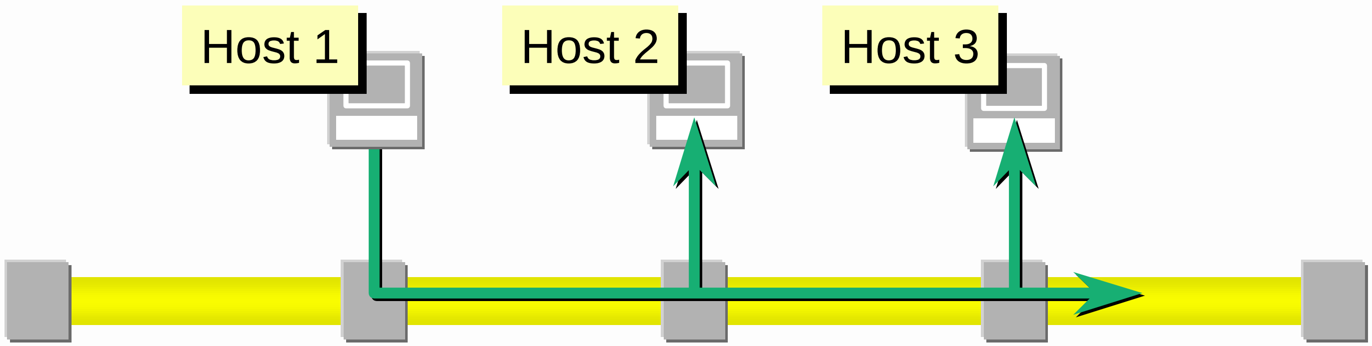


Here is a typical shared LAN.

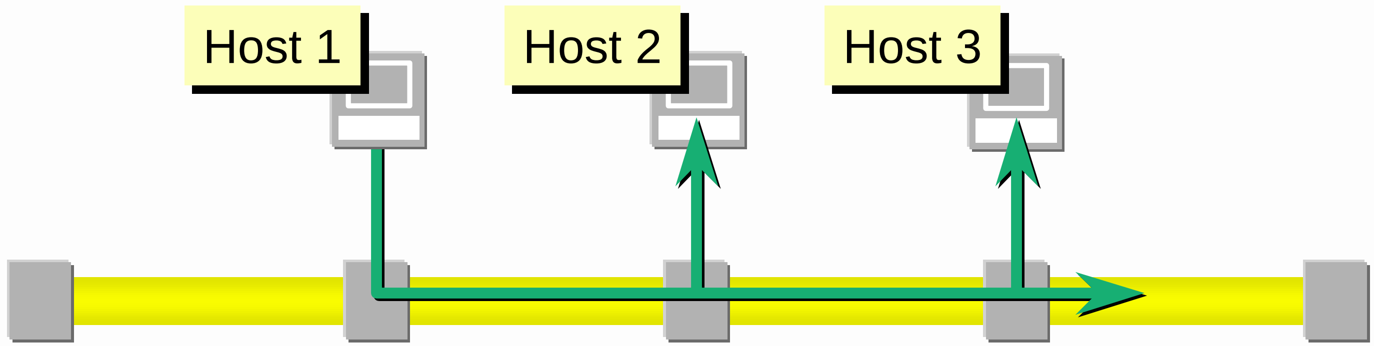
Multiple attached hosts, usually PCs, share a common communication channel.



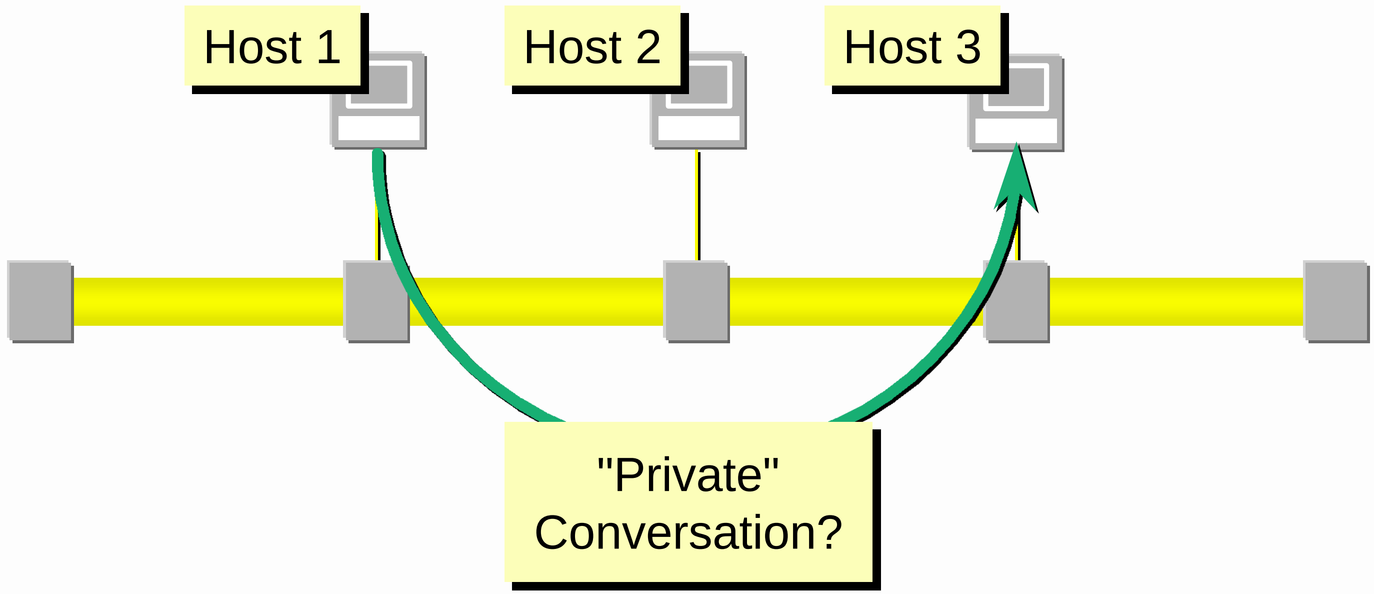
If Host 1 transmits information into the shared channel, then it "passes by" all of the other devices connected to the channel.



If Host 1 transmits information into the shared channel, then it "passes by" all of the other devices connected to the channel.



Note that the exact physical representation of "passing by" is installation-specific. This older Ethernet installation is a bus-based system. Ring-based LANs and hub-based LANs may look different but they operate under the same assumption that all devices in the shared channel will be able to see each others' messages.



There are two reasons that this broadcast nature in a LAN is not universally desirable.

First, we often wish to send messages between two specific devices, such as Host 1 and Host 3 without other devices, such as Host 2, being able to see the information.

Second, in a busy LAN, other devices' conversations should not be allowed to influence the performance of stations that are not involved in the conversation.

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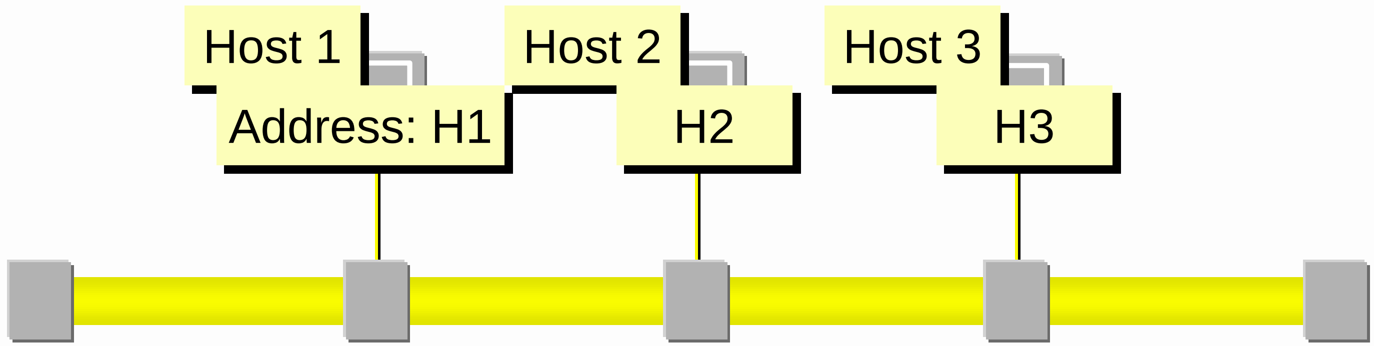
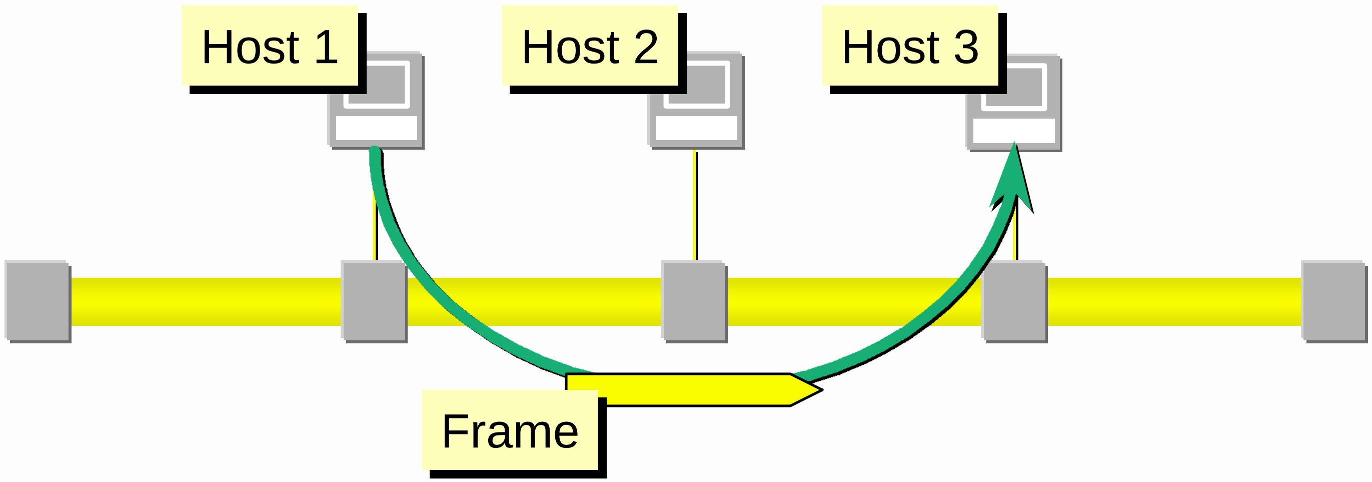
Before we look at the performance aspects, let's see how we can achieve the impression of privacy in our shared LAN systems.



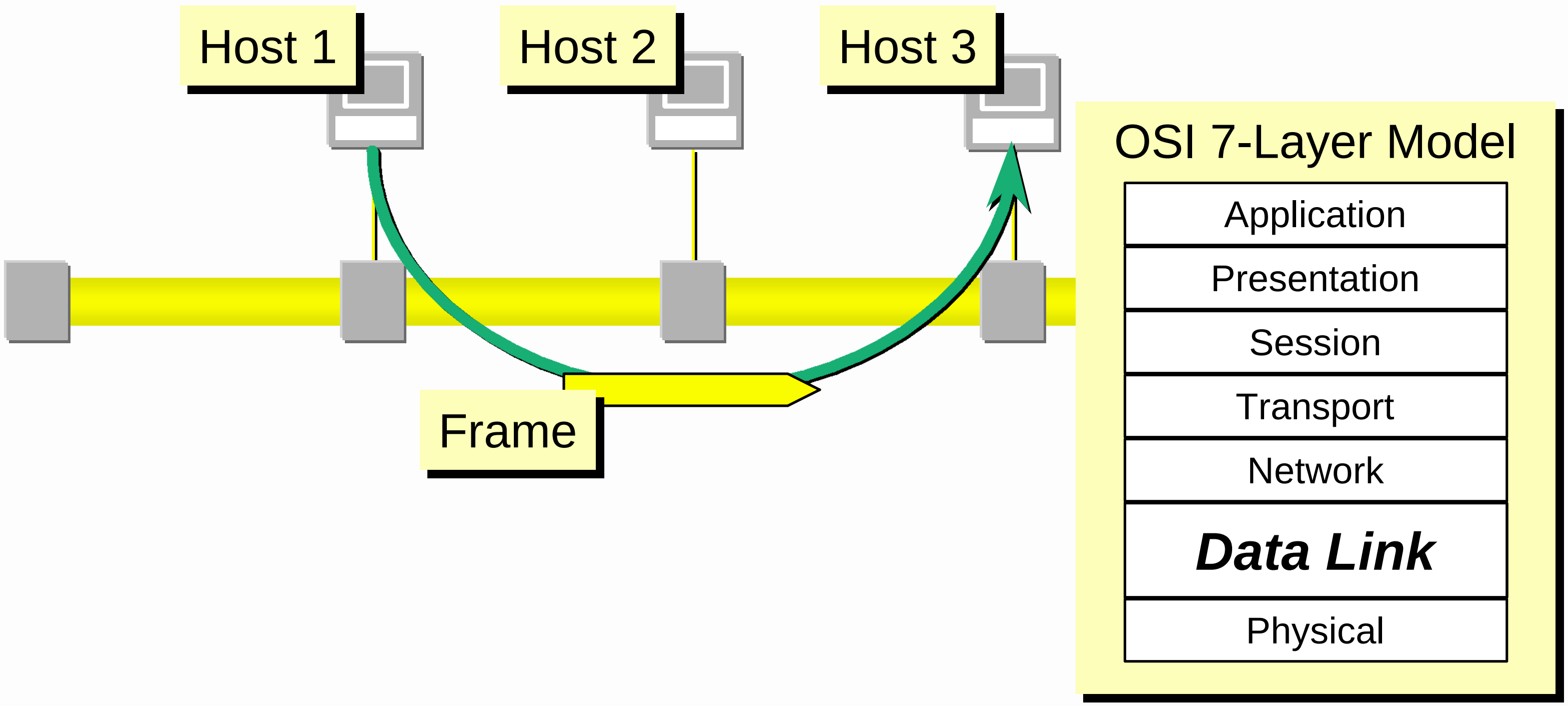
To achieve privacy in our conversations, we can give each device on the shared channel a unique address, and transmit our information in units which contain the address of the destination device.

We can also include our own, sending address, so that the other device can reply directly to us.

Note that these addresses operate at the MAC Layer of the OSI model, as discussed in the module “Addressing in LANs”.

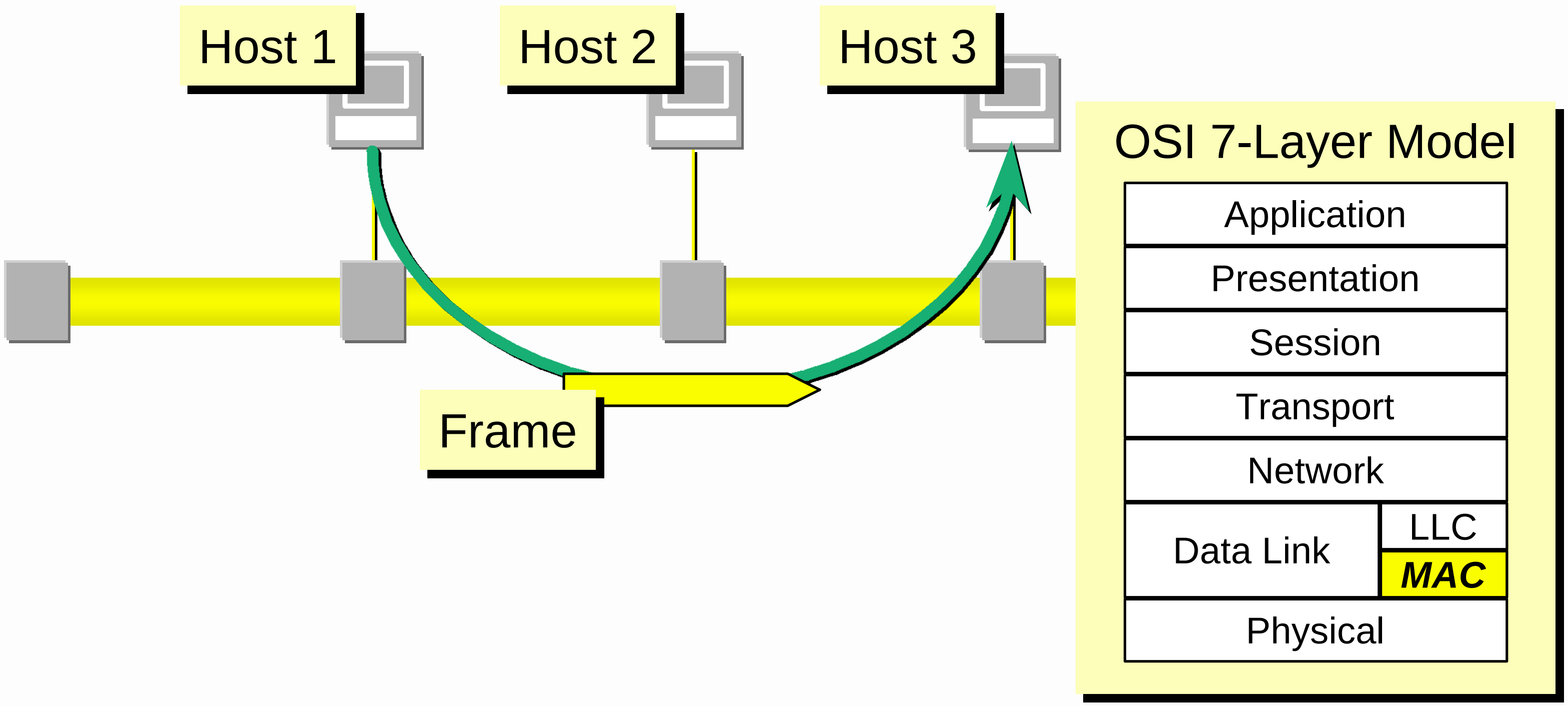


The information units that contain these addresses are called frames.

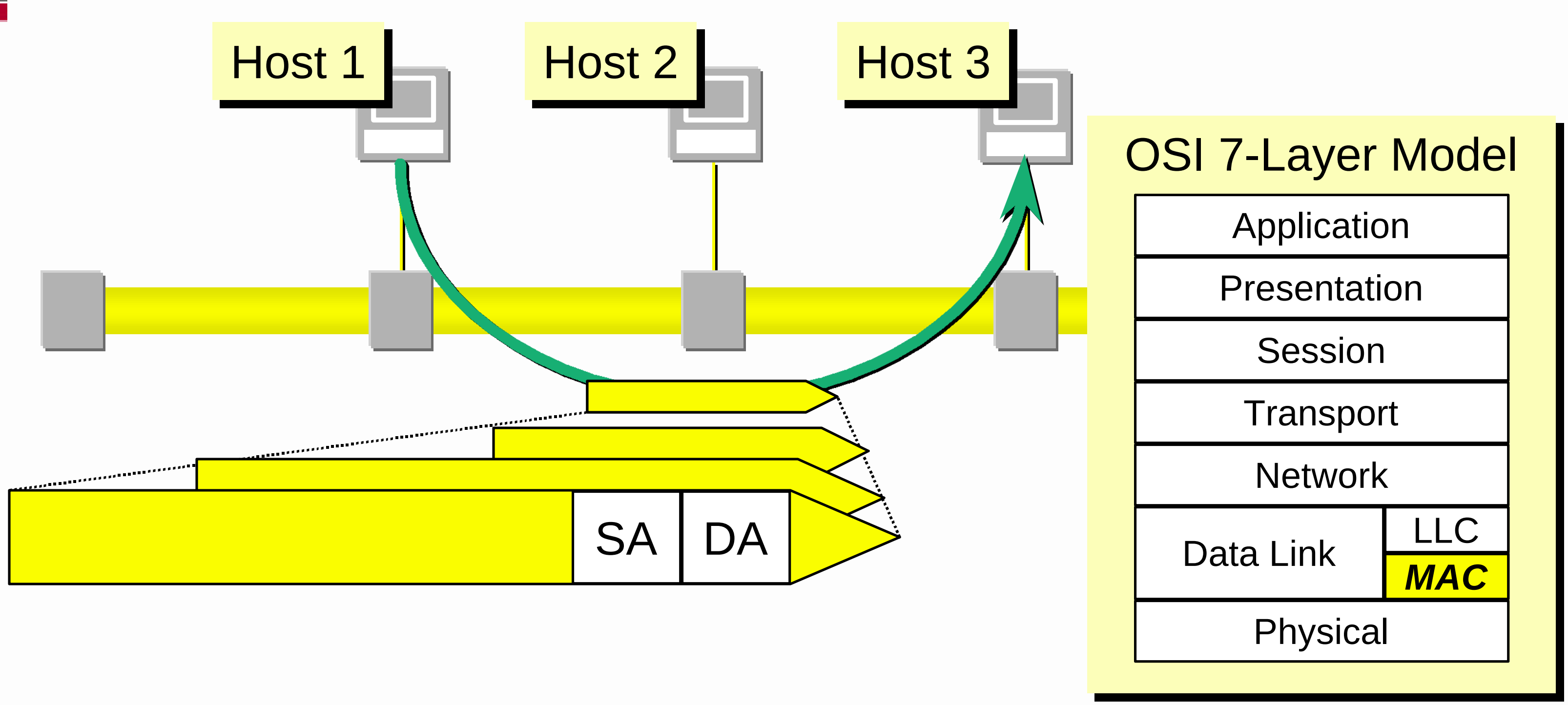


The information units that contain these addresses are called frames.

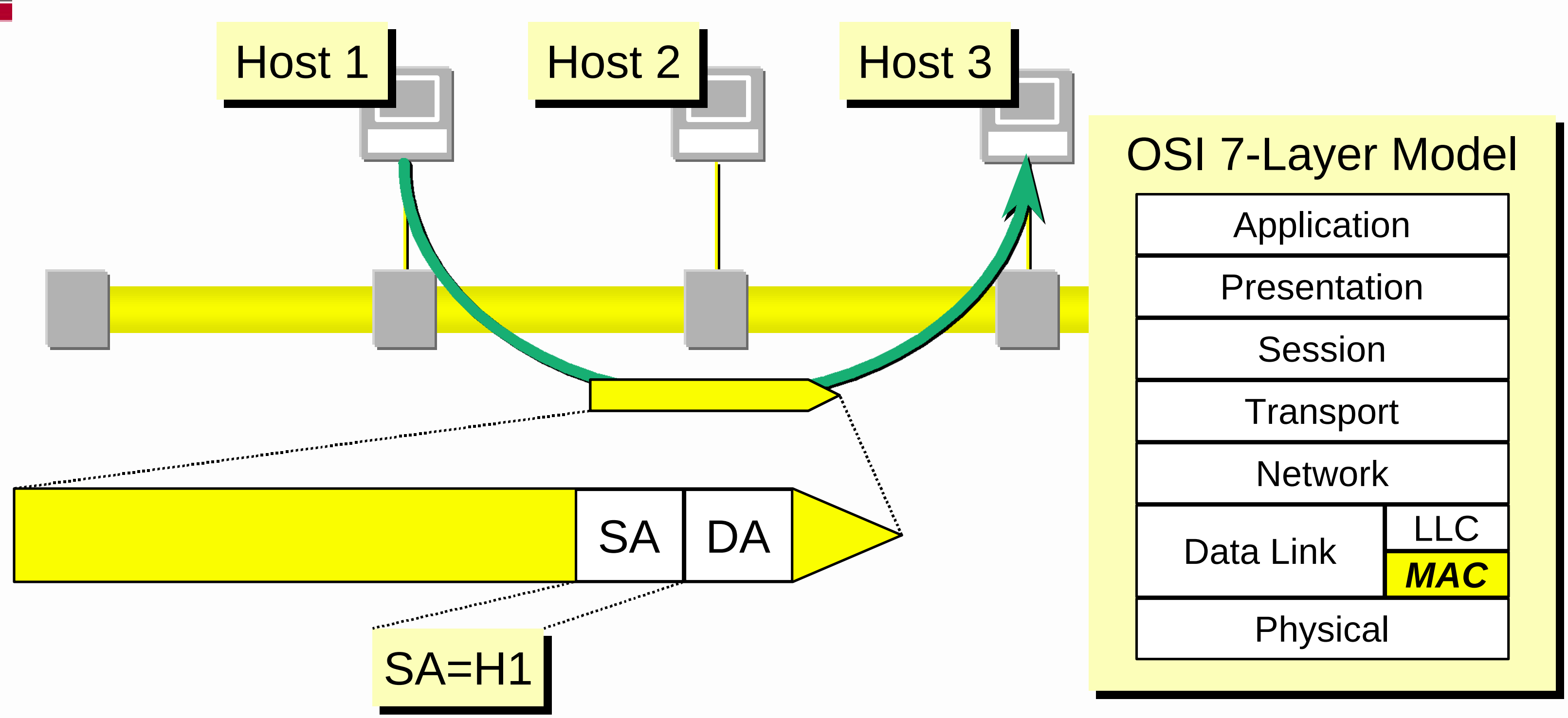
They are descibed by protocols that are part of the OSI Data Link Layer.



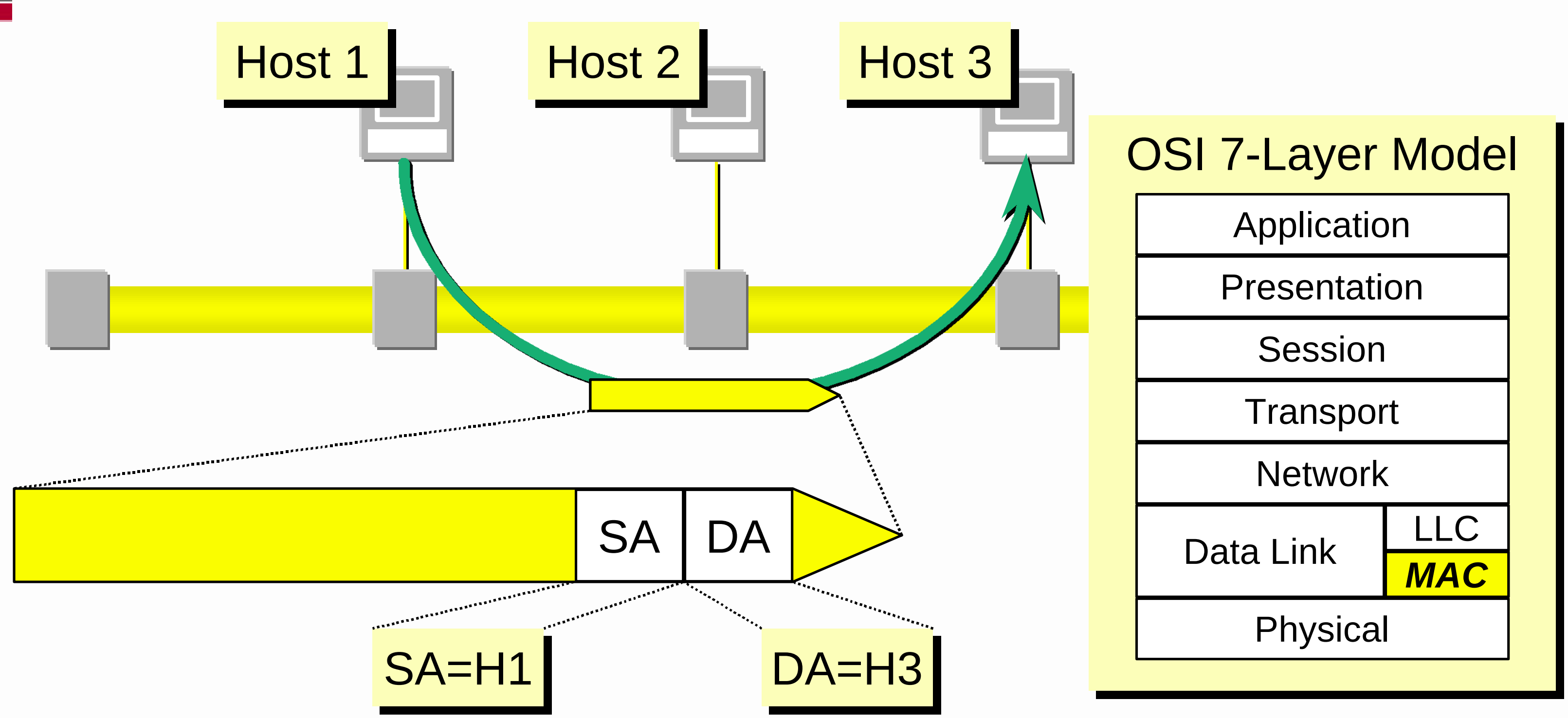
In particular, frames are part of the Media Access Control (MAC) sub-layer of the Data Link Layer, and so they are often referred to as MAC Frames.



The Destination (DA) and Source (SA) MAC address that we use to create private conversations over a shared LAN segment are stored within the frame.

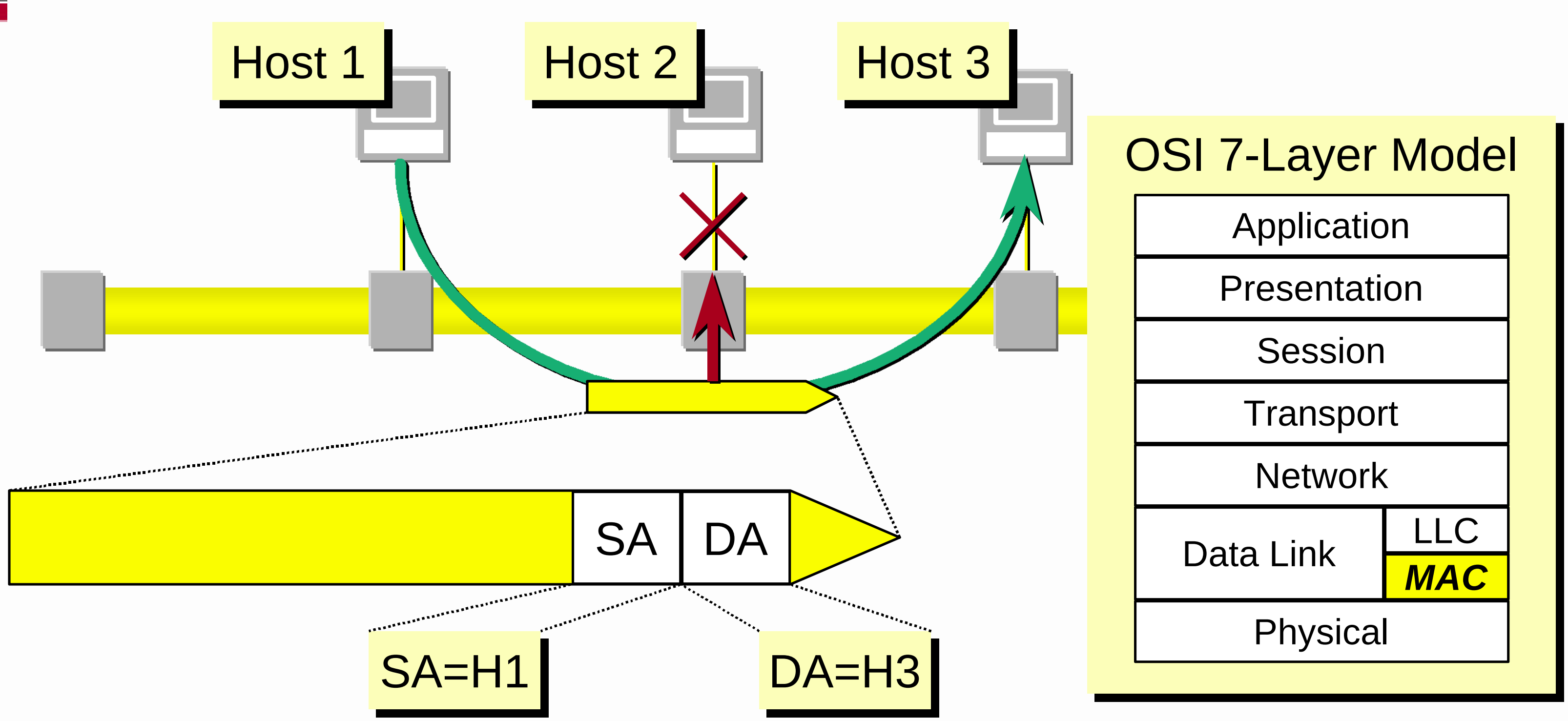


For this frame, the Source Address (SA) will be set to Host 1's MAC address, H1.

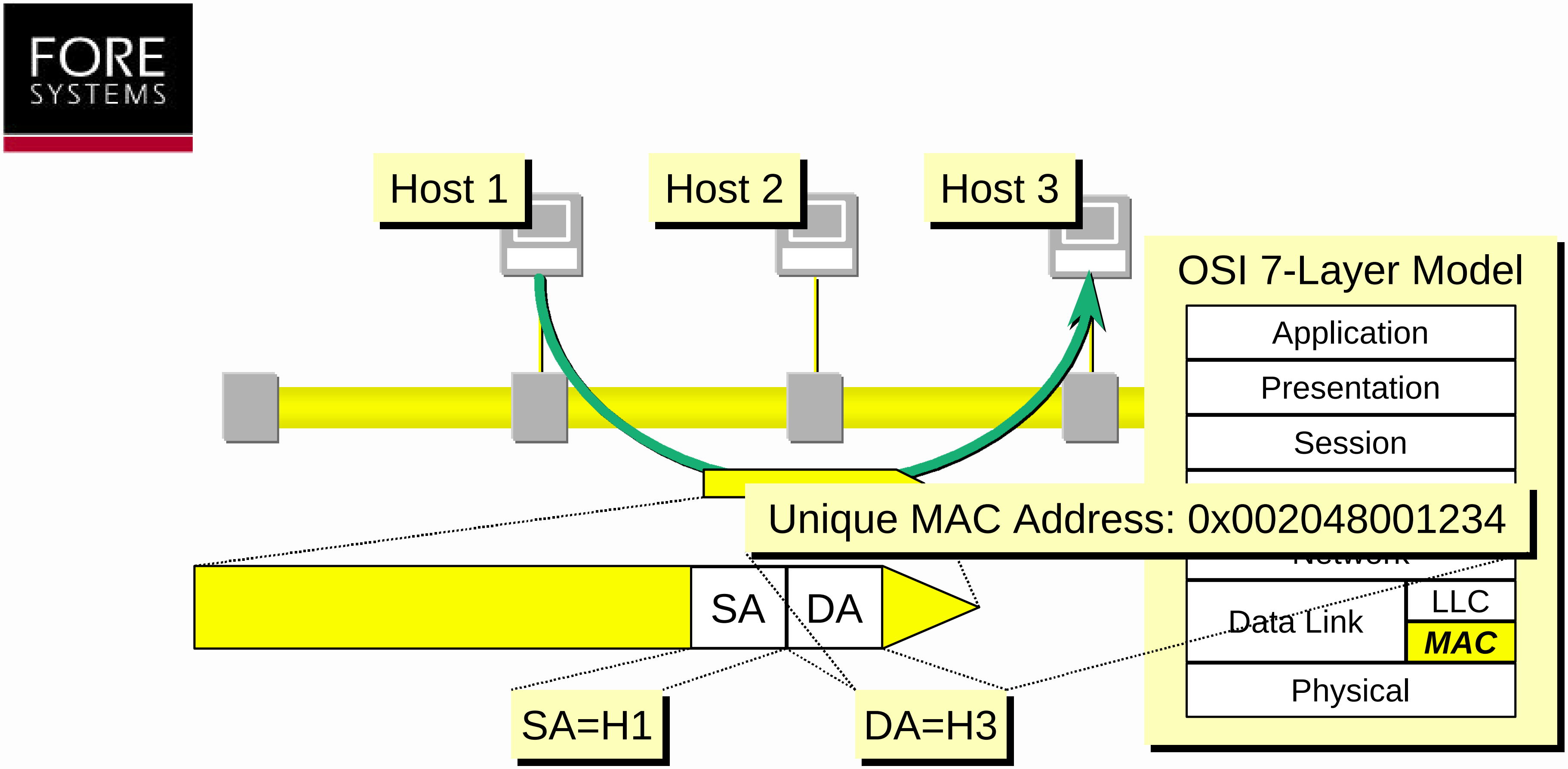


For this frame, the Source Address (SA) will be set to Host 1's MAC address, H1.

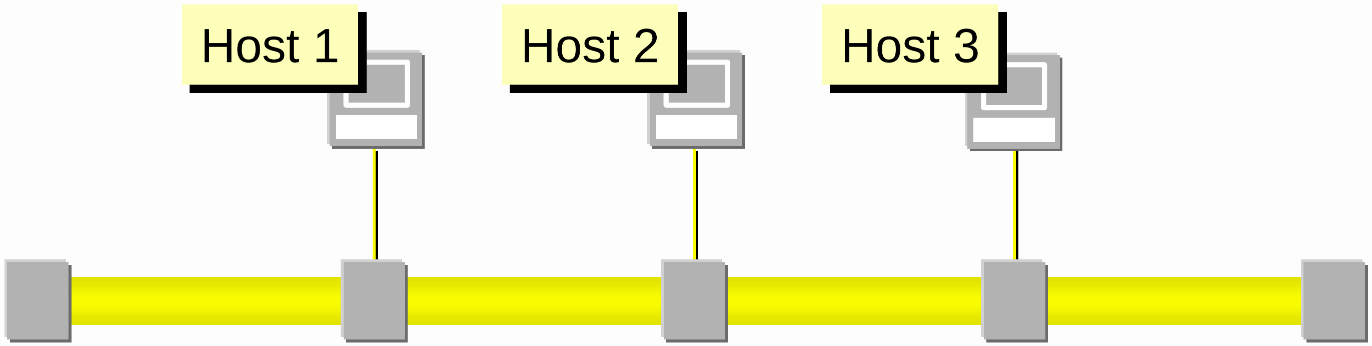
The Destination Address (DA) is set to Host 3's MAC address, H3.



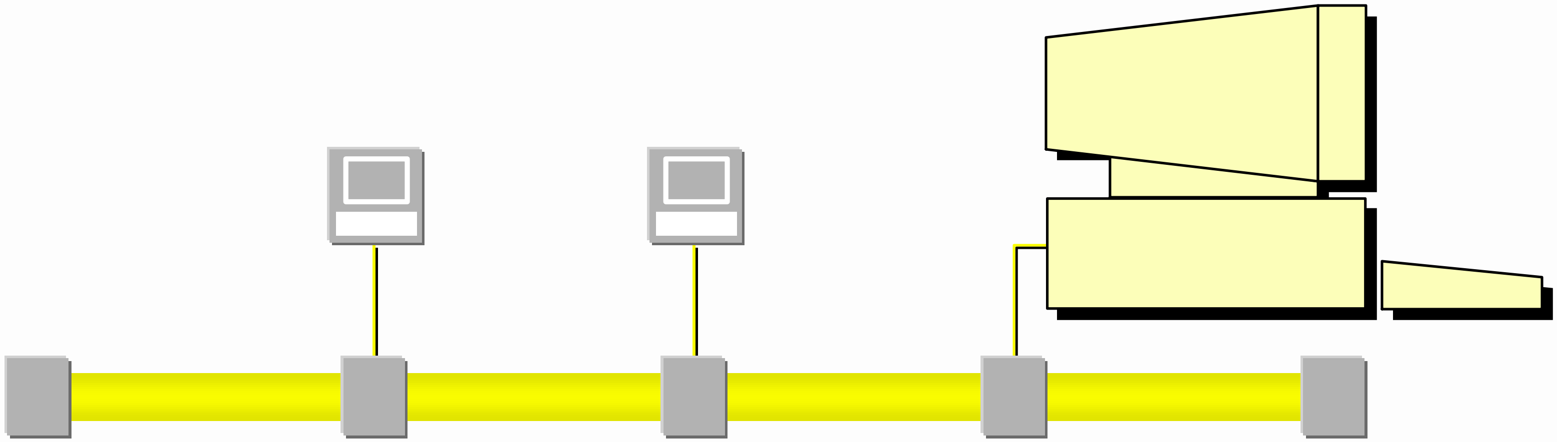
When this frame is transmitted, Host 2 should not receive it, and so a "private conversation" has been created.



Note that real MAC addresses are 48-bits long, and I'm using this abstract representation to keep things simple (and to save room on the diagrams!).

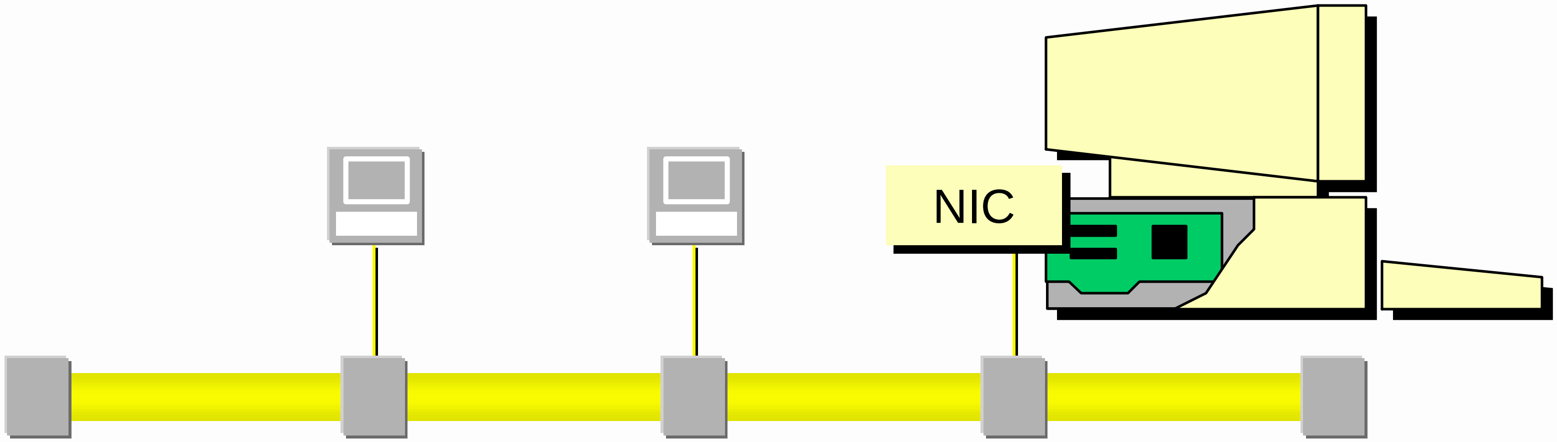


Let's have a closer look at how this privacy is achieved.



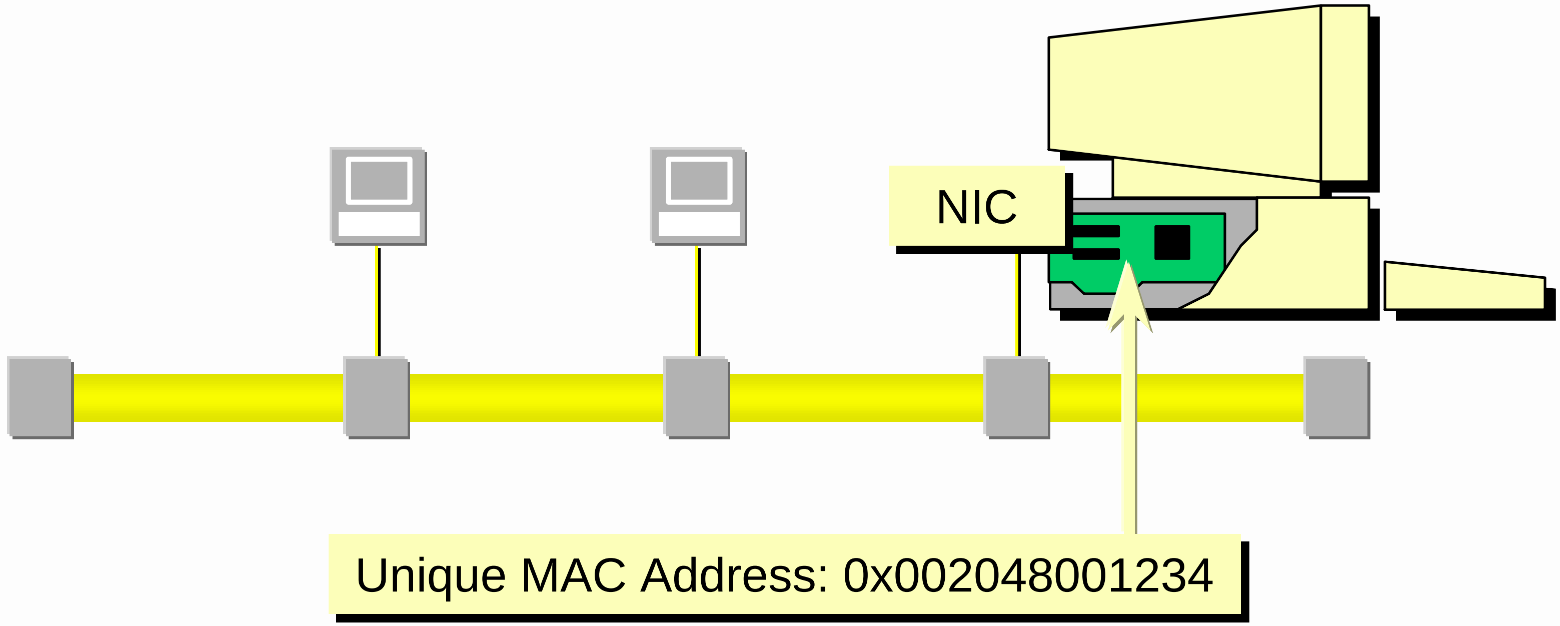
Let's have a closer look at how this privacy is achieved.

I'm going to zoom in on Host 3.



Each of the hosts on the LAN needs to be fitted with an adapter allowing it to connect to the cable that provides access to the shared LAN segment.

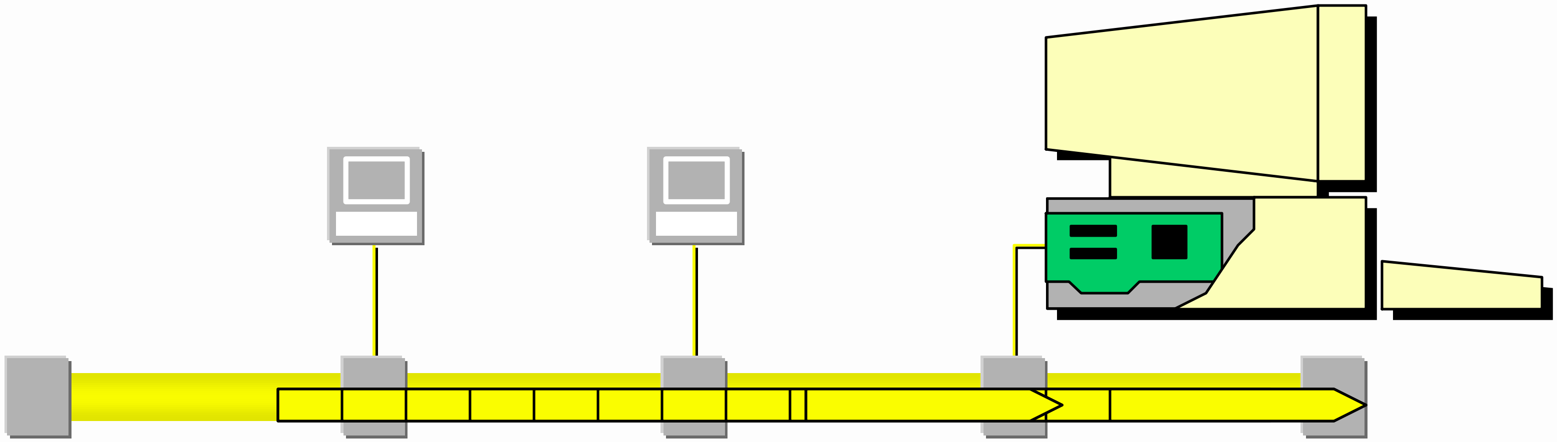
These adapters are generally known as Network Interface Cards (NICs).



Inside each NIC there is the unique, 48-bit MAC address to which this adapter will respond. This address is called the Unicast Address of the NIC.

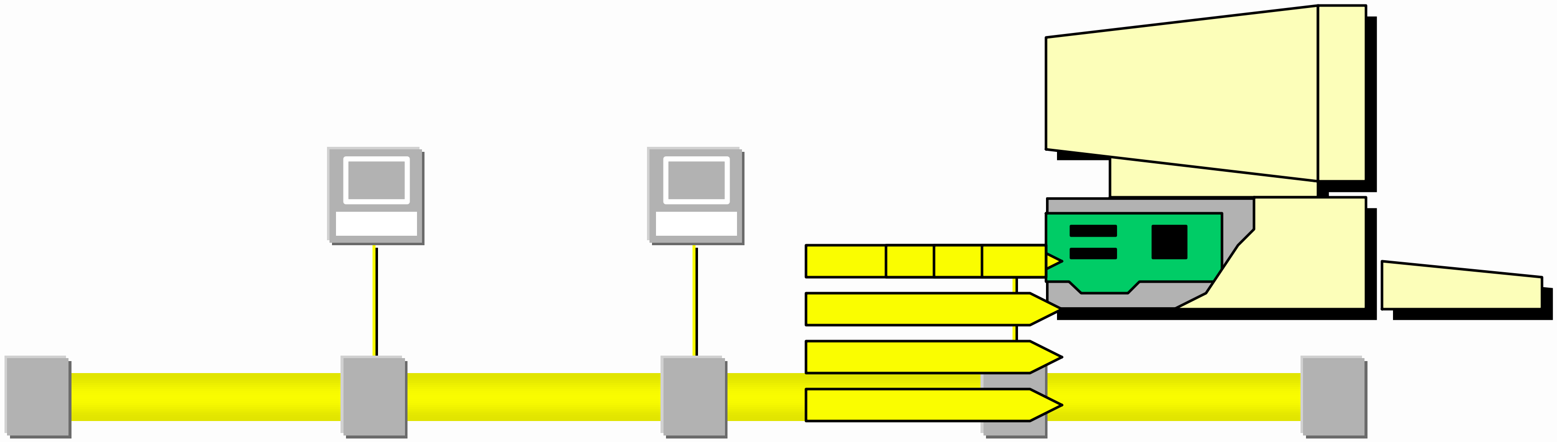
The response is controlled by high-speed address recognition circuits that are implemented in hardware on the NIC.

These circuits are capable of scanning the bitstream at full wire speed for any Destination Address on a frame that matches the NIC's unique, unicast address.



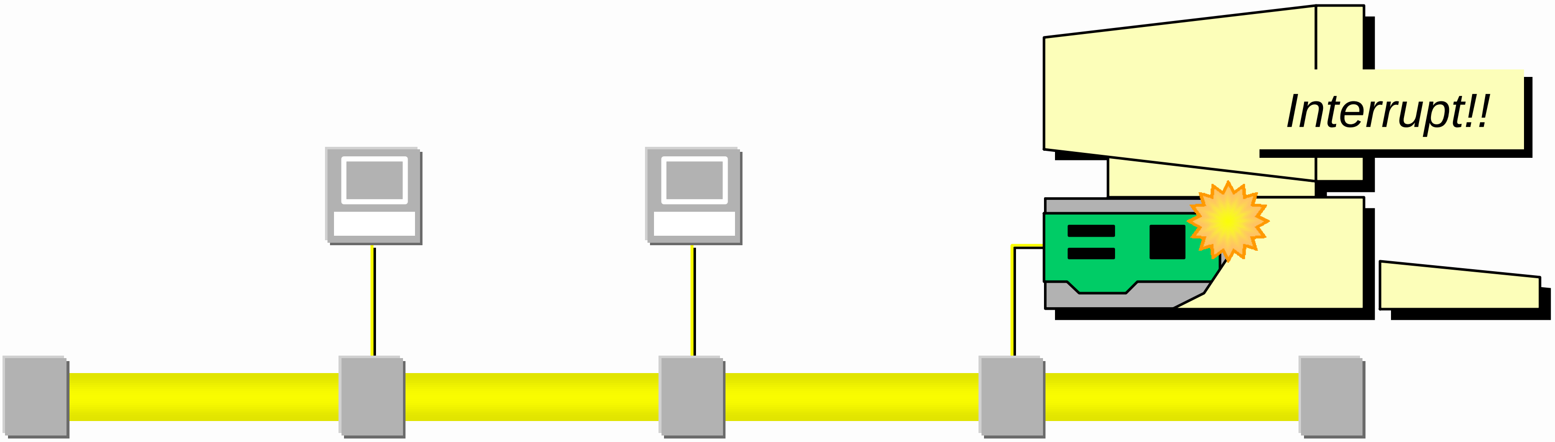
As MAC frames zoom by on the shared LAN segment, the address recognition circuits in each NIC will be examining the Destination MAC Addresses on each frame.

If a match is found...

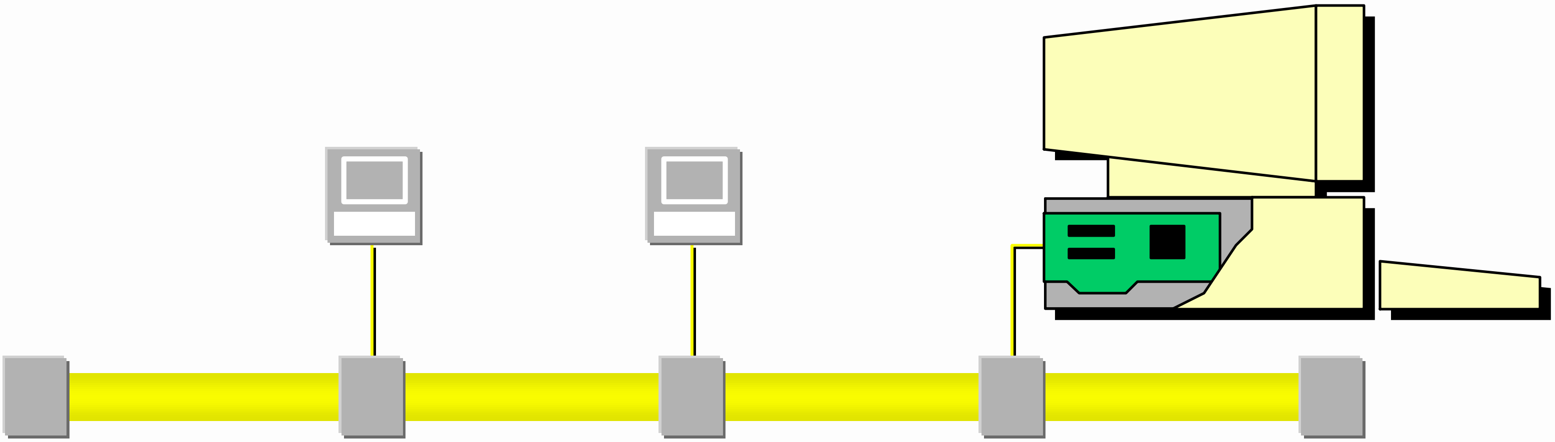


…then the entire MAC frame will be copied into the receive buffer on the NIC.

Note that the term copy implies that the "original" frame that was recognised is allowed to continue along the LAN segment.



When the frame arrives in the receive buffer of the NIC, an interrupt is signalled to the CPU of the PC.

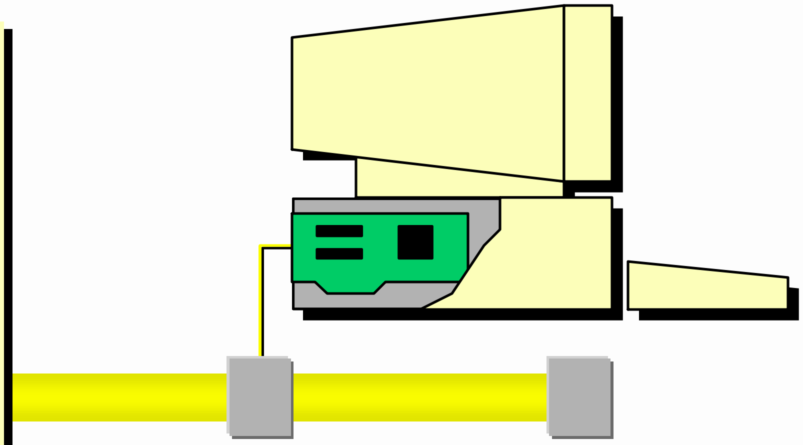


The interrupt causes the PC to stop whatever it's doing and to service the interrupt, and check that this frame contains relevant information.

Typically this involves a check by the Network Layer software of the PC to verify that the Network Layer protocol and addressing is correct.

LAN Frame Reception

- All hosts potentially see all frames on LAN segment
- Frames can be sent "privately" by using the Unicast Address
- Address recognition circuits on the NIC scan for destination unicast MAC address
- If match is found, frame is "received" by copying to receive buffer and CPU is interrupted



Here are the four vital concepts we need to understand in conventional LAN unicast frame reception.

When we emulate LAN behaviour with an ATM network, this is exactly the kind of behaviour expected by the communication protocols we use.

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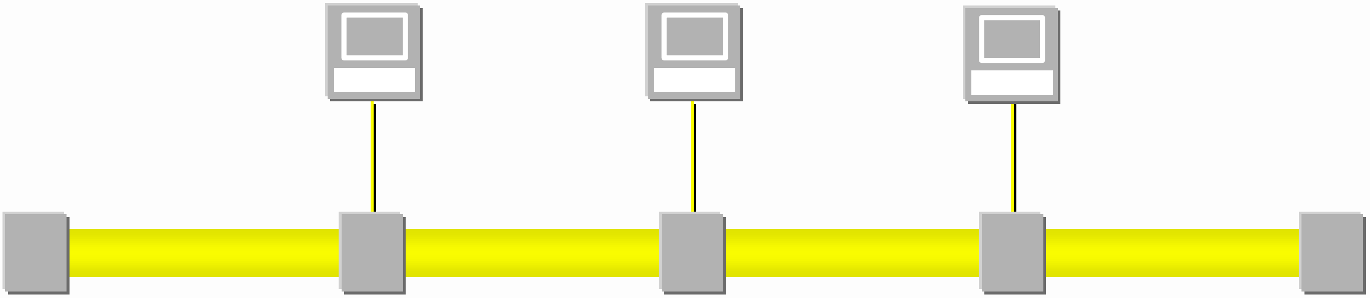
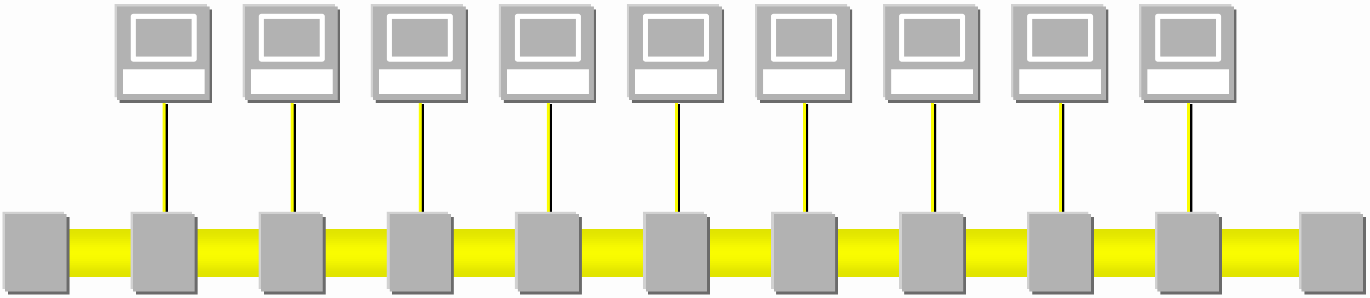
So far I've discussed the idea of a private conversation on a LAN segment using unicast addressing.

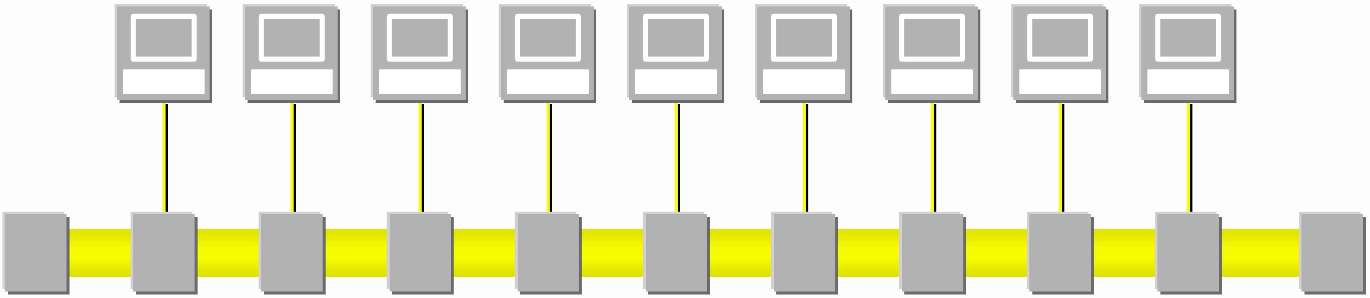
In this next section I'll discuss another address type called multicasts, which are used to transmit the same piece of information to more than one device on the network.



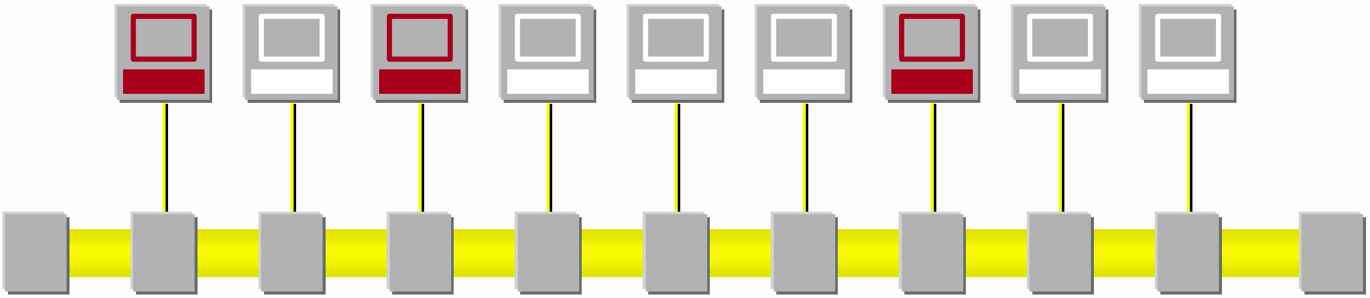
Suppose we have a slightly larger population of hosts on our LAN segment...



…like so.

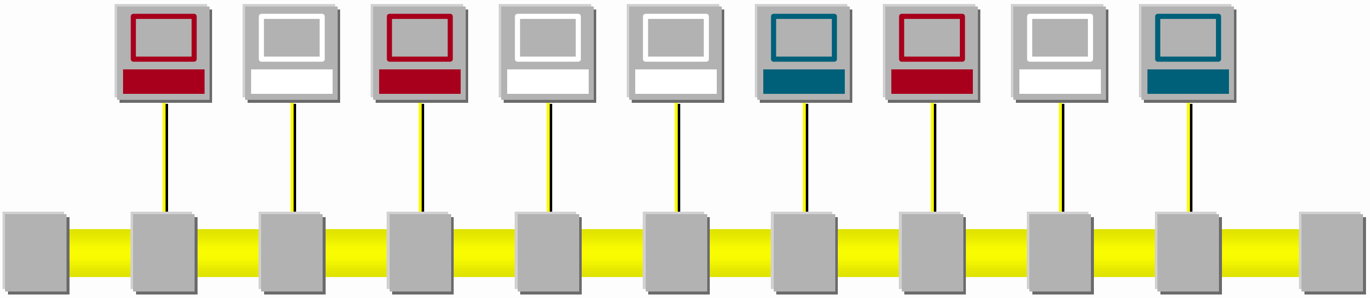


Let's also imagine that these PCs are running applications that are specific to the person using the PC.



Let's also imagine that these PCs are running applications that are specific to the person using the PC.

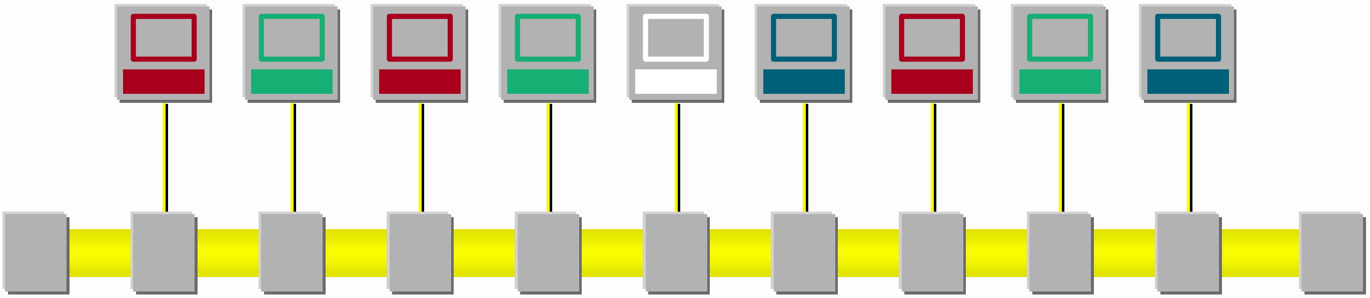
…these three "red" machines are used by salesfolk.



Let's also imagine that these PCs are running applications that are specific to the person using the PC.

…these three "red" machines are used by salesfolk…

…these two "blue" machines are used by engineers...

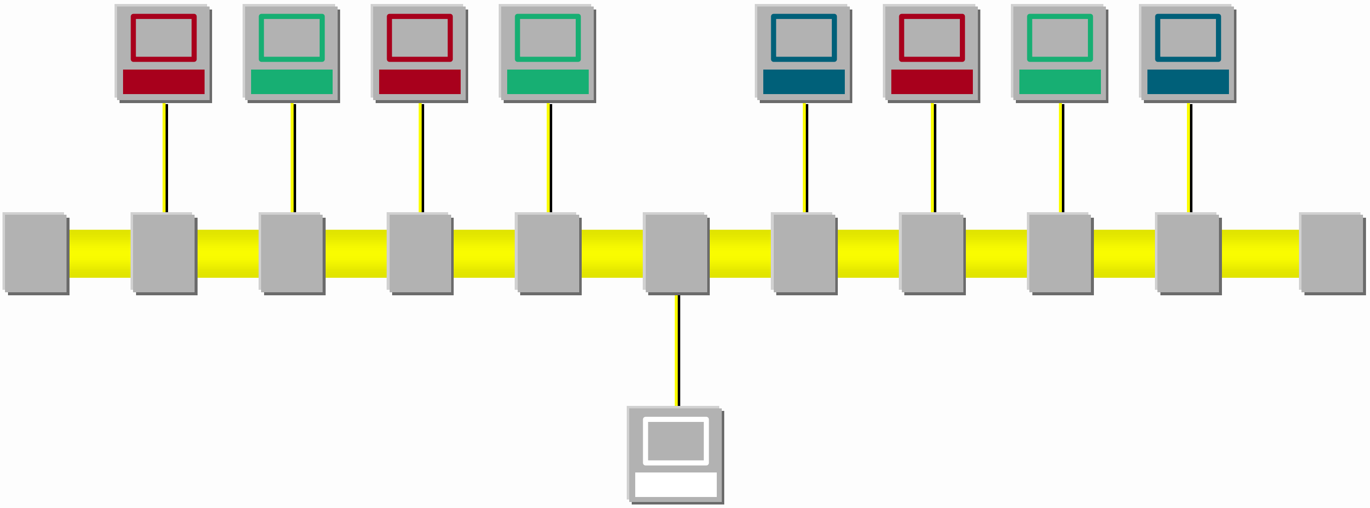


Let's also imagine that these PCs are running applications that are specific to the person using the PC.

…these three "red" machines are used by salesfolk…

…these two "blue" machines are used by engineers…

…these three "green" machines are used by administrators...



Let's also imagine that these PCs are running applications that are specific to the person using the PC.

…these three "red" machines are used by salesfolk…

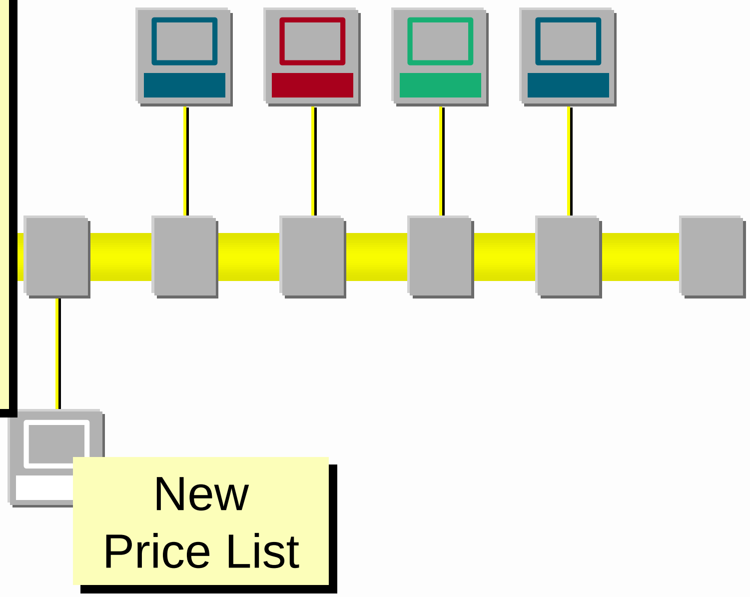
…these two "blue" machines are used by engineers…

…these three "green" machines are used by administrators…

…and the "white" machine is used as a server for all groups.

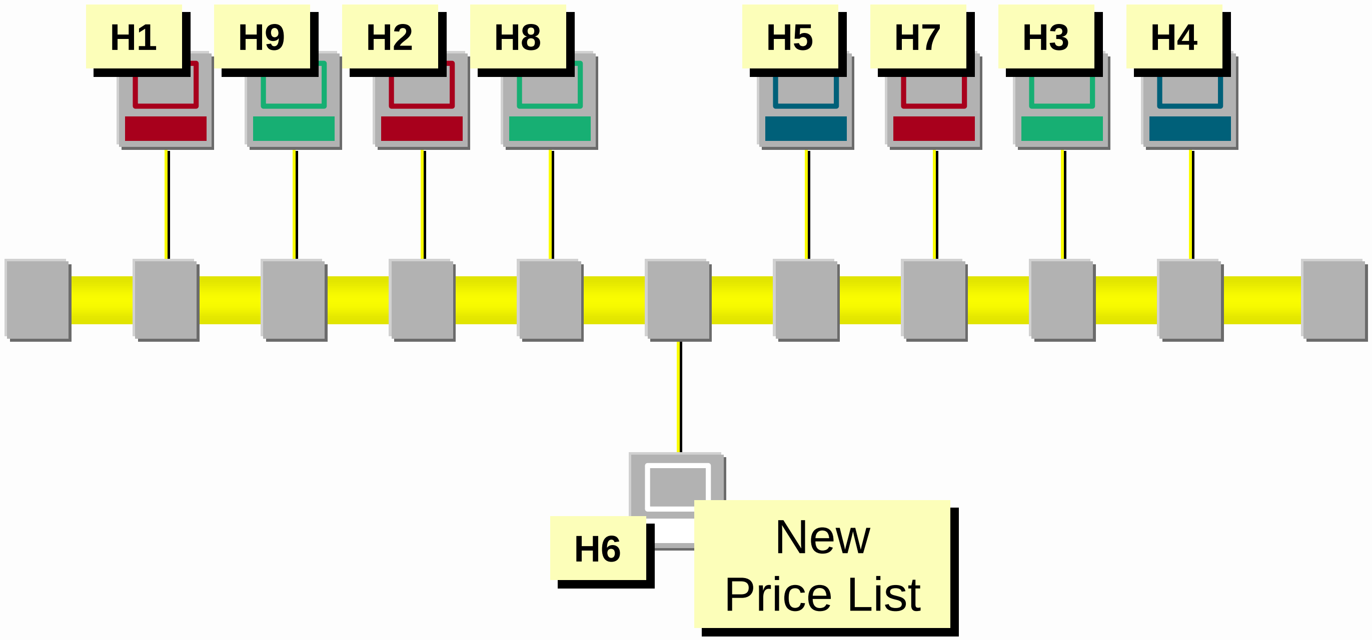
3 Options

- Send separate Unicasts to each member of "sales" group
- Send one message that reaches all members of LAN segment
- Send to the "sales" multicast group



Suppose there was an announcement about a change in the price list, and this had to be sent to all the salesfolk.

There are three ways that the server can make sure that all the salesfolk get this information.

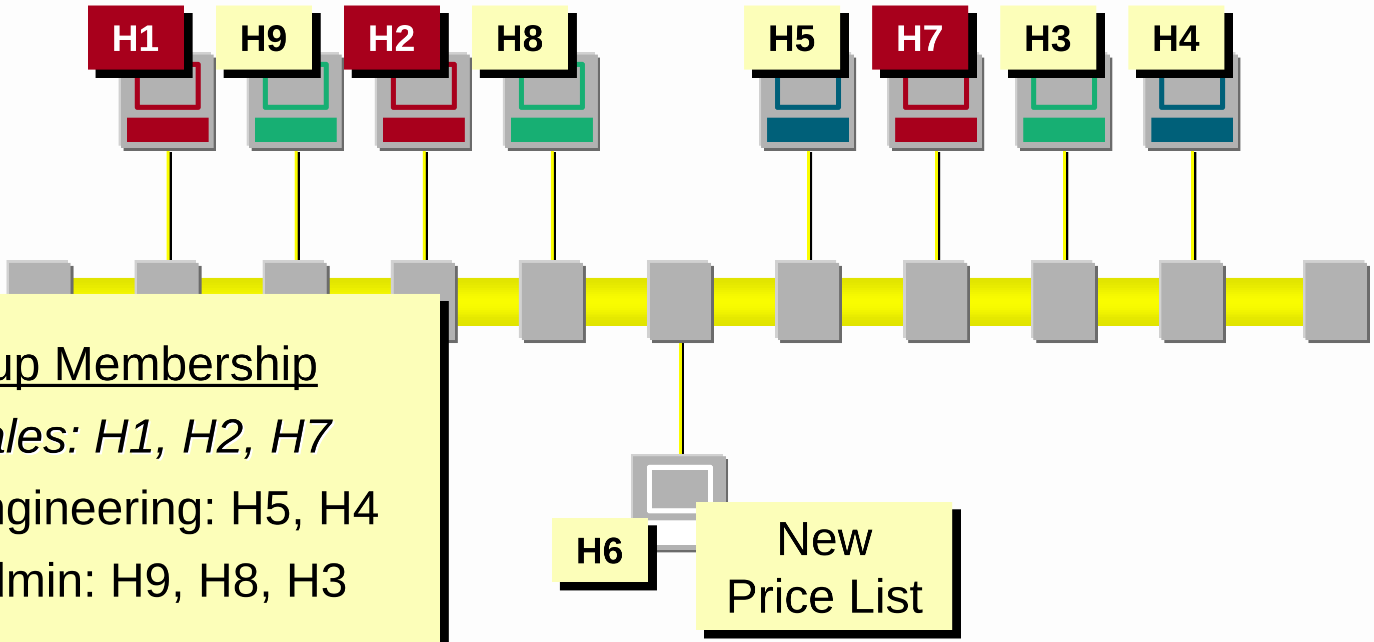


The first method requires the server to send an explicit unicast message to each member of the Sales group in turn.

Remember that each member of the LAN segment has a unique, unicast address.

Each frame sent will be received by only one member of the group because it is addressed to the unicast destination for that member.

Option 1: Multiple Unicast Messages to Group Members

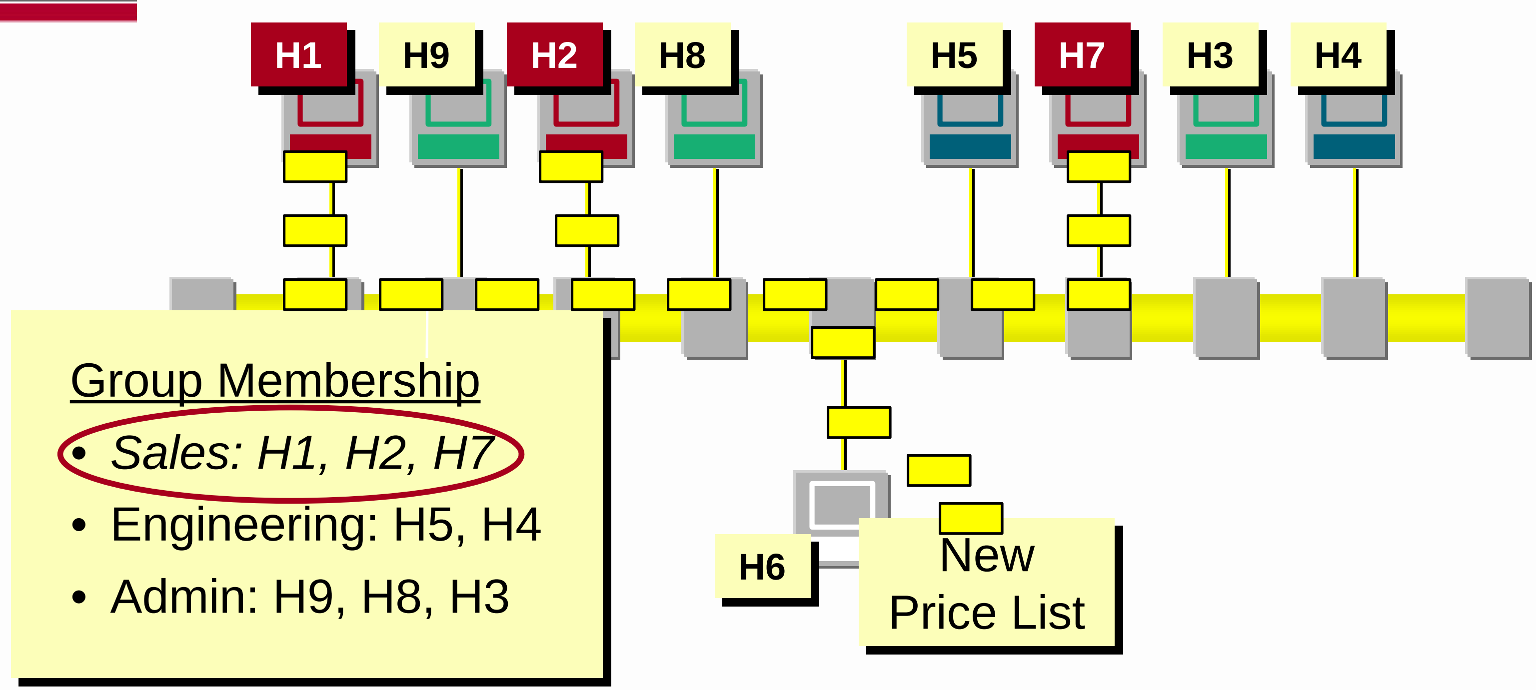


<u>Group Membership</u>

- *Sales: H1, H2, H7*
- Engineering: H5, H4
- Admin: H9, H8, H3

In order to send frames to the sales group (the red PCs, remember), the server will need a list of unicast MAC addresses belonging to the sales group...

Option 1: Multiple Unicast Messages to Group Members



The server can now send one or more frames that represent the message about the new Price List to each member in turn. Note the number of frames sent by the server will be equal to the number of members in the group multiplied by the number of frames in the complete message.

So, for example, a message made up of a thousand frames (about 1MByte) sent to three group members will consist of three thousand individual frame transmissions. As the number of group members increases, so does the work done by the server.

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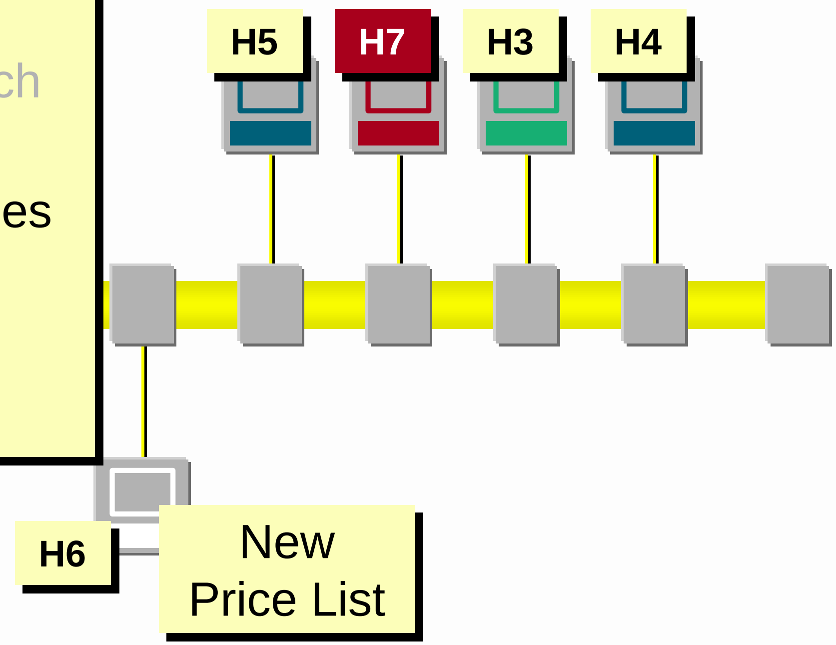
3 Options

- Send separate Unicasts to each member of "sales" group
- Send one message that reaches all members of LAN segment
- Send to the "sales" multicast group

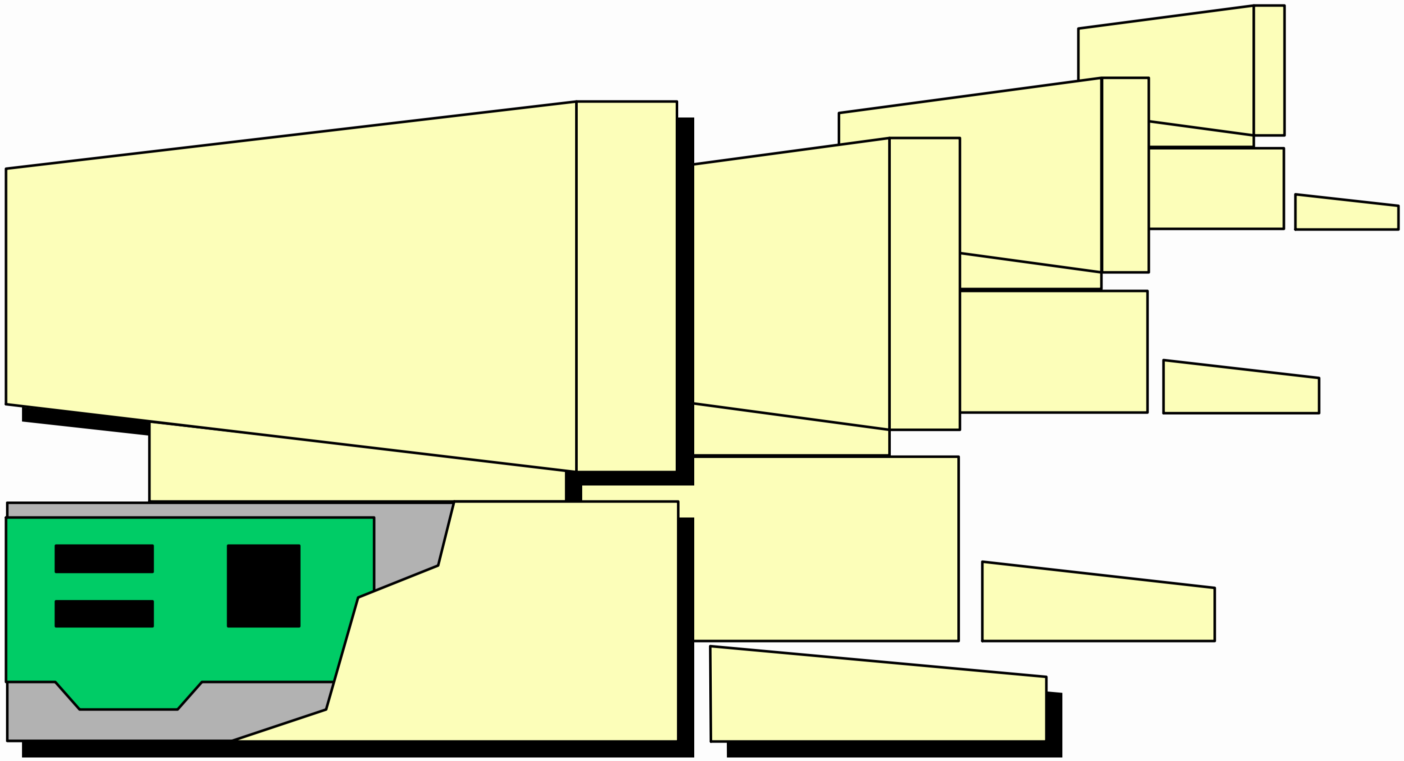


To make the operation of higher layer communication protocols more straightforward, NIC circuits also recognise another type of address.

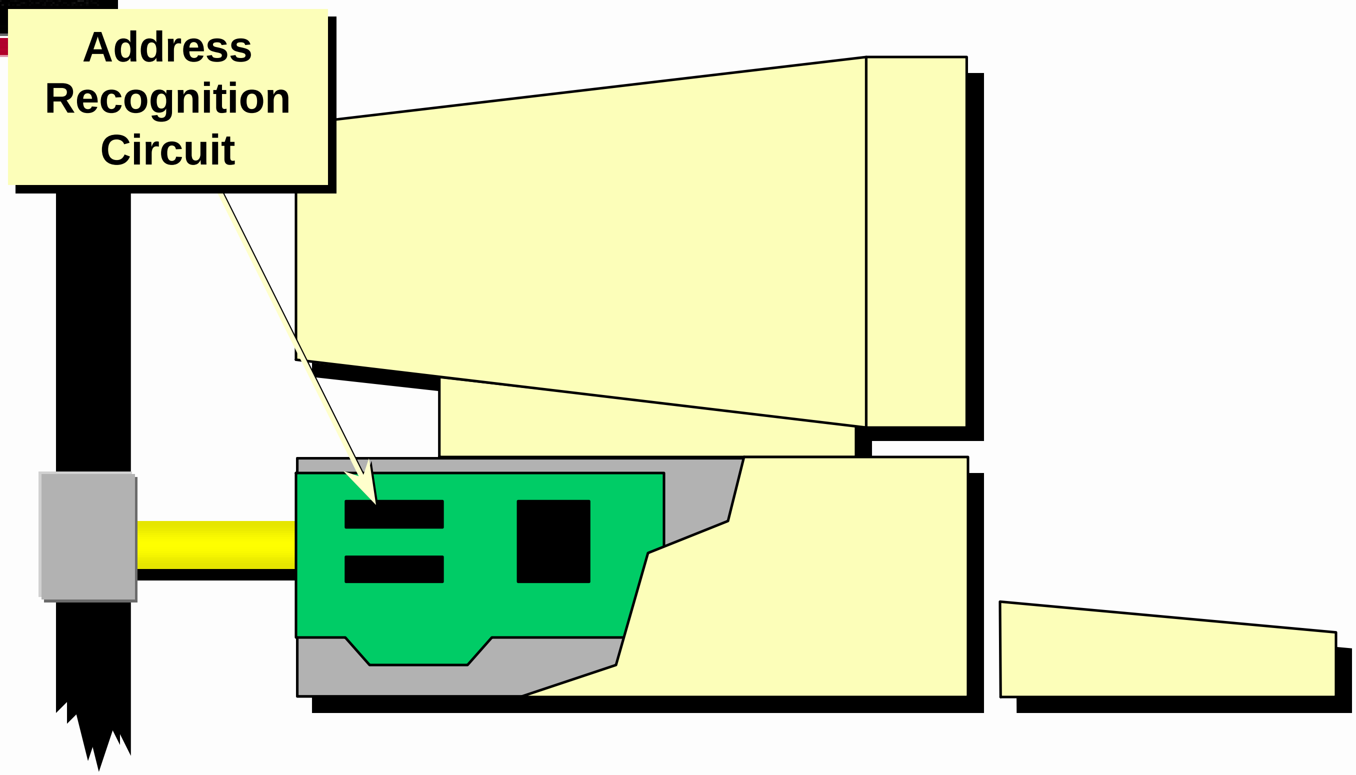
These addresses are known as broadcasts and multicasts.

Broadcast addresses are intended to be received and copied by all NICs on the LAN segment.

Multicast addresses allow us to send a single message onto the LAN that will be received by more than one NIC.

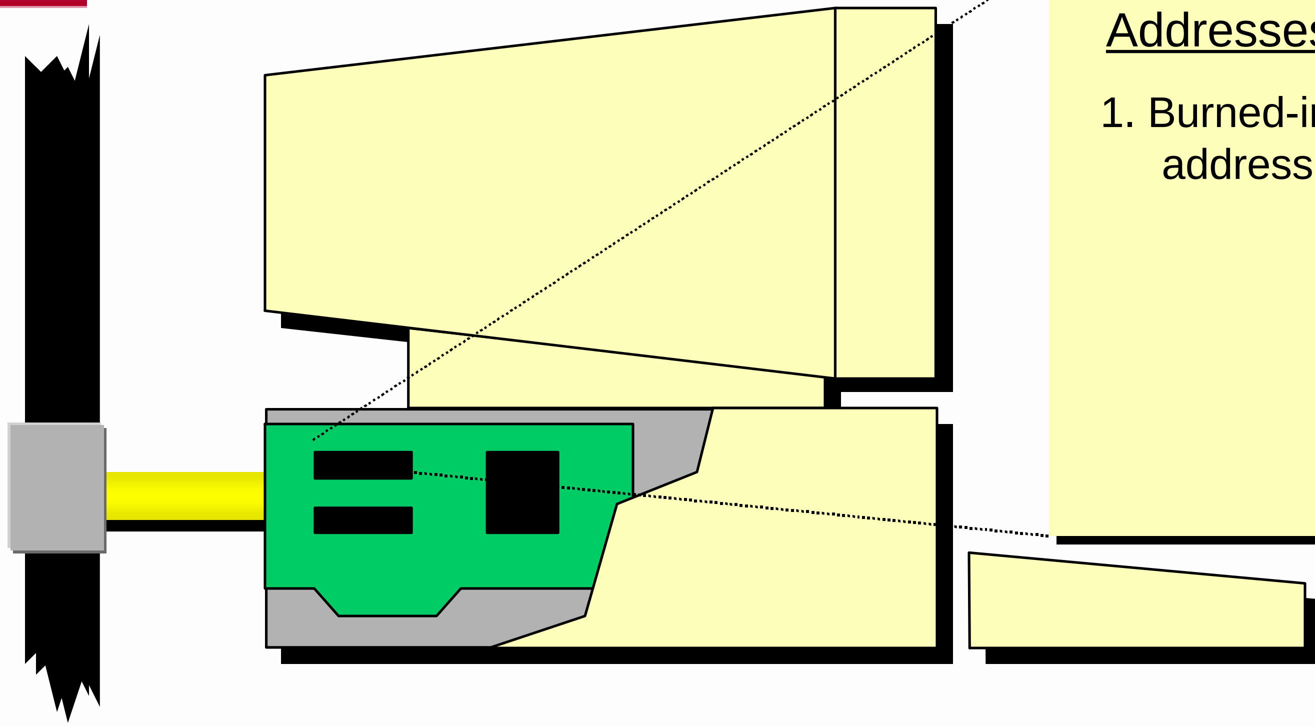


Let's take a closer look at the NIC.



Each NIC is using the address recognition circuits to decide which frames passing by on the LAN cable should be received by the host.

But the NIC is actually able to receive more than just one unicast address...

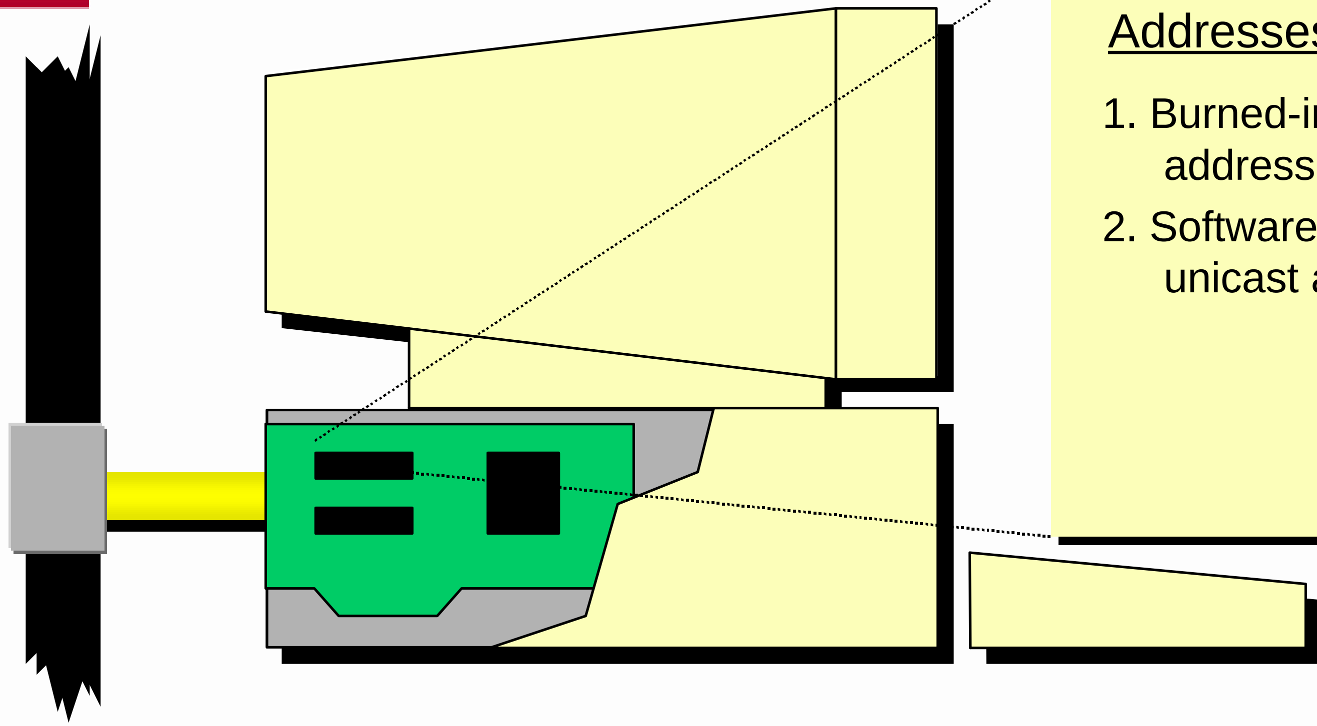


Addresses I Recognise

1. Burned-in unicast
   address

The unicast address I've described so far is usually known as the burned-in address because it is permanently stored inside a component on the NIC.

The manufacturer of the NIC is assigned a unique block of MAC addresses, and is responsible for allocating unique unicast addresses within this block to each NIC it produces.



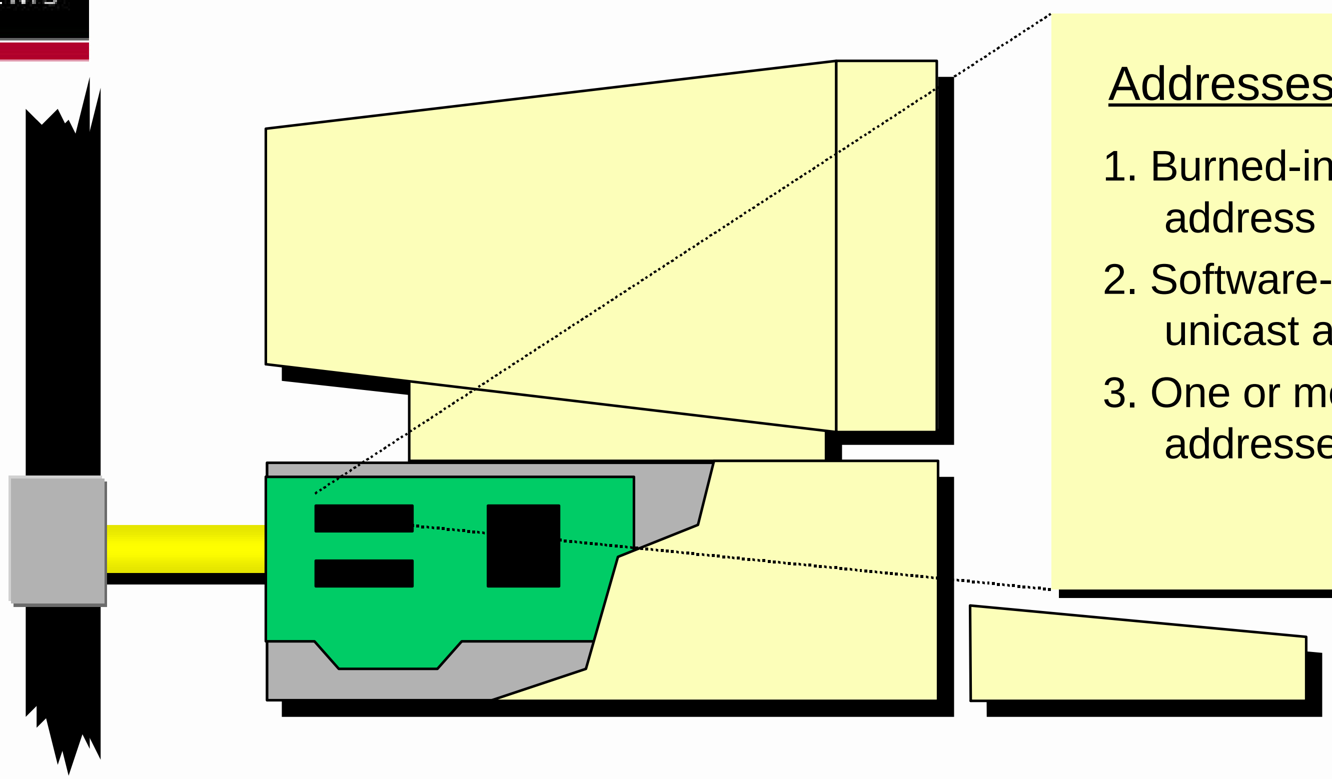
Addresses I Recognise

1. Burned-in unicast address
2. Software-configured unicast address

Although the burned-in address is permanent, it's possible to instruct the NIC to respond to a different, software-configured address using the NIC device drivers.

This address replaces the burned in address temporarily (until the NIC is powered-down or restarted).

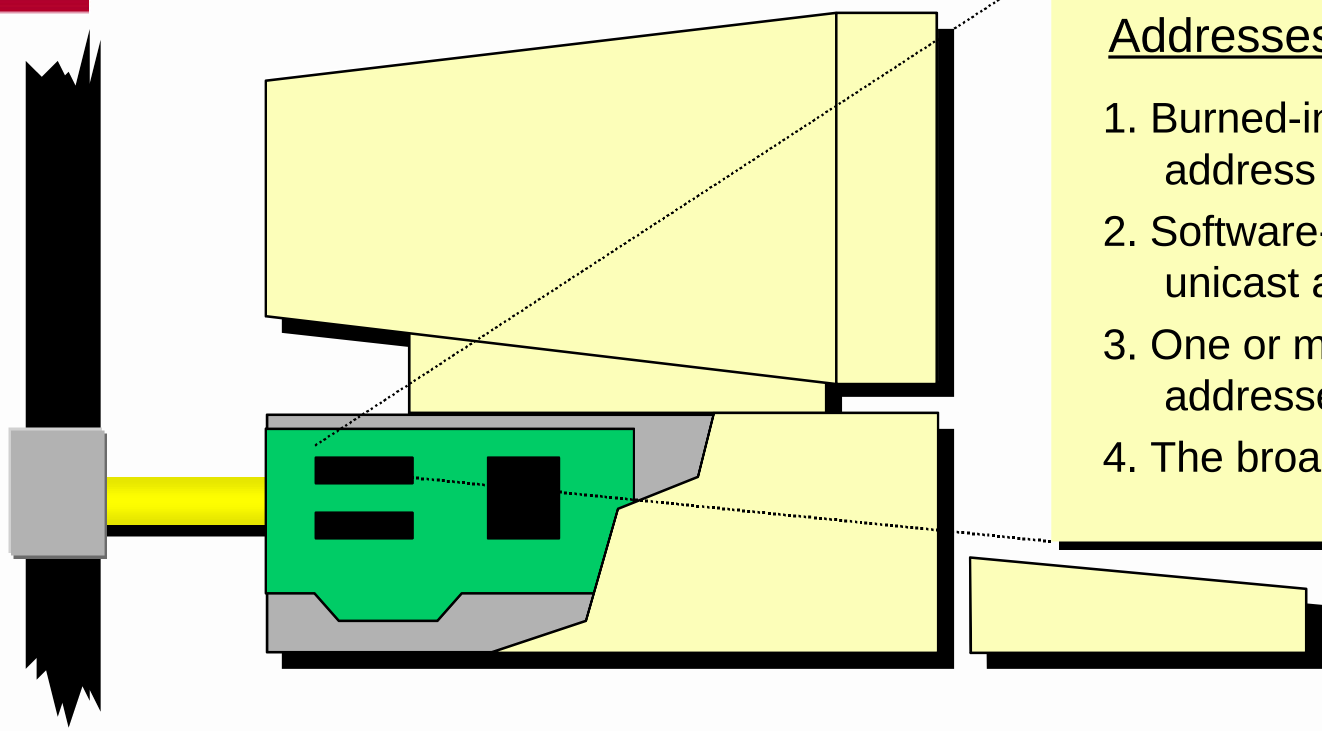
Software-configured addresses are required by some communications stacks (eg. SNA, DECnet).



Addresses I Recognise

1. Burned-in unicast address
2. Software-configured unicast address
3. One or more multicast addresses

The NIC may also be software-configured with a small number (usually 8) multicast addresses.



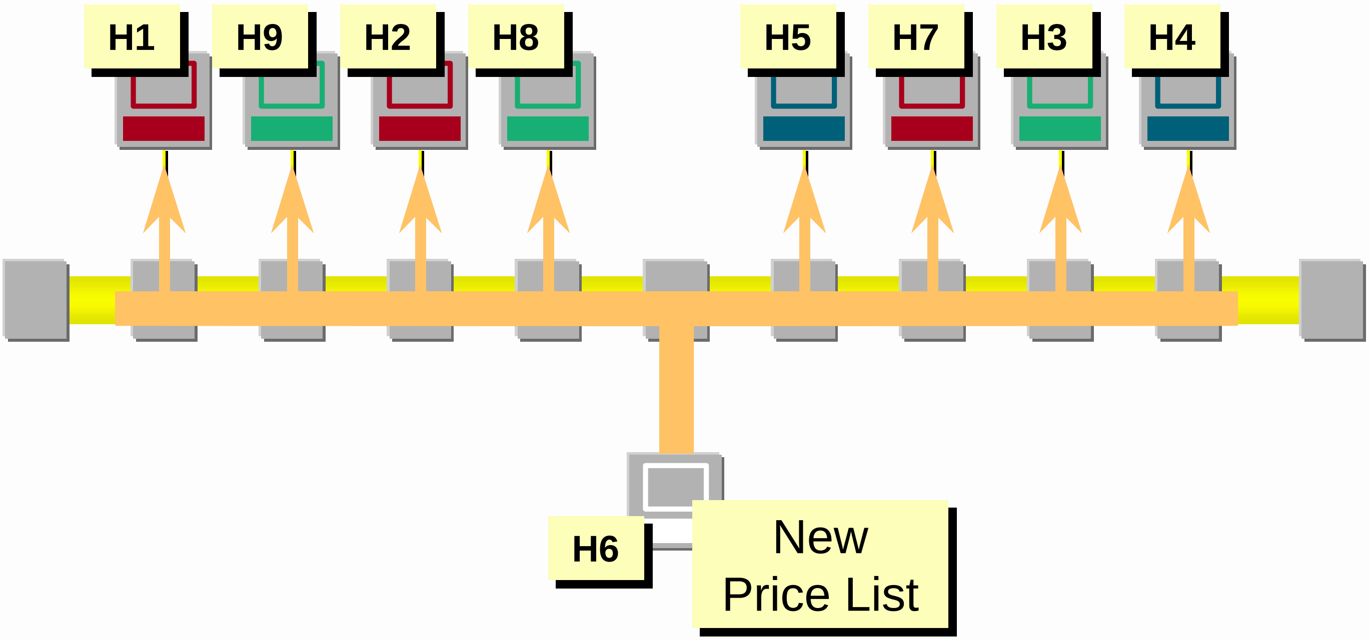
Addresses I Recognise

1. Burned-in unicast address
2. Software-configured unicast address
3. One or more multicast addresses
4. The broadcast address

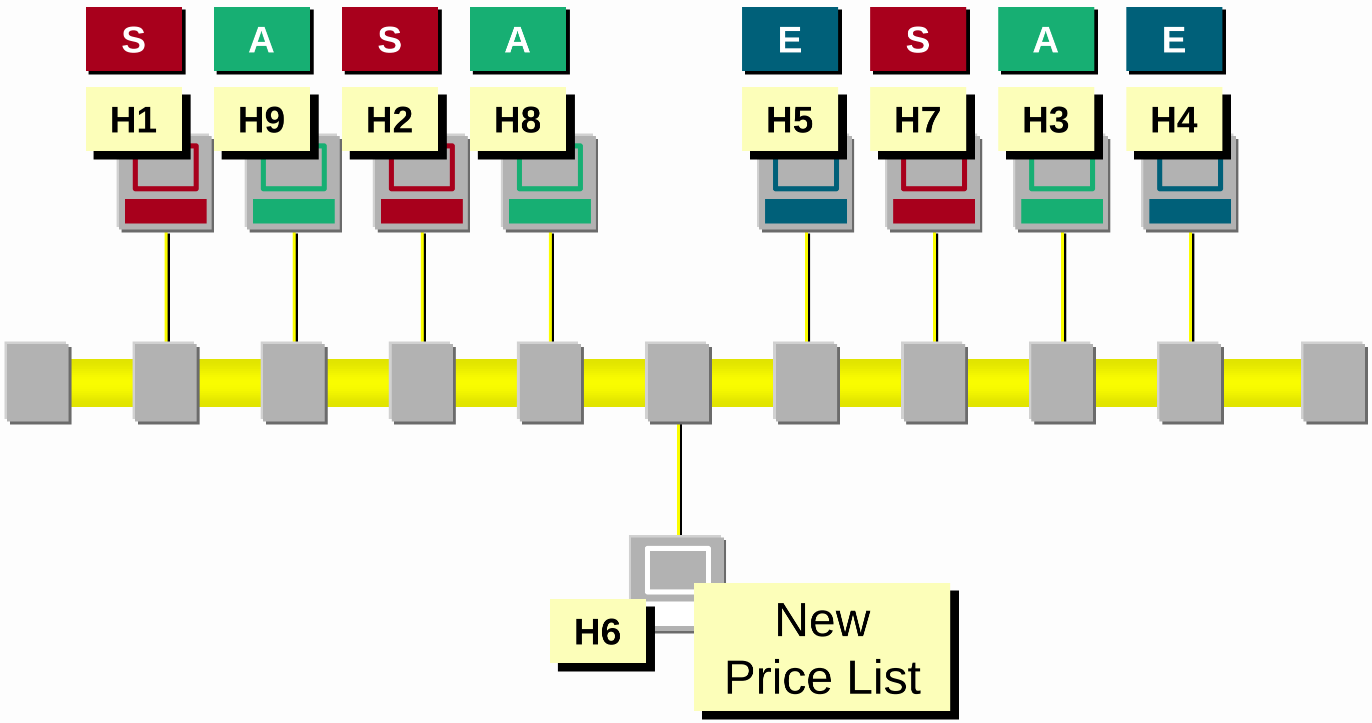
Finally, all NICs should respond to a special form of multicast address known as the broadcast address.

A broadcast message is intended to be received and copied by all hosts that are on the LAN segment.

Many older communication protocols make use of broadcasts to discover hosts on the LAN, or to advertise services to LAN clients.



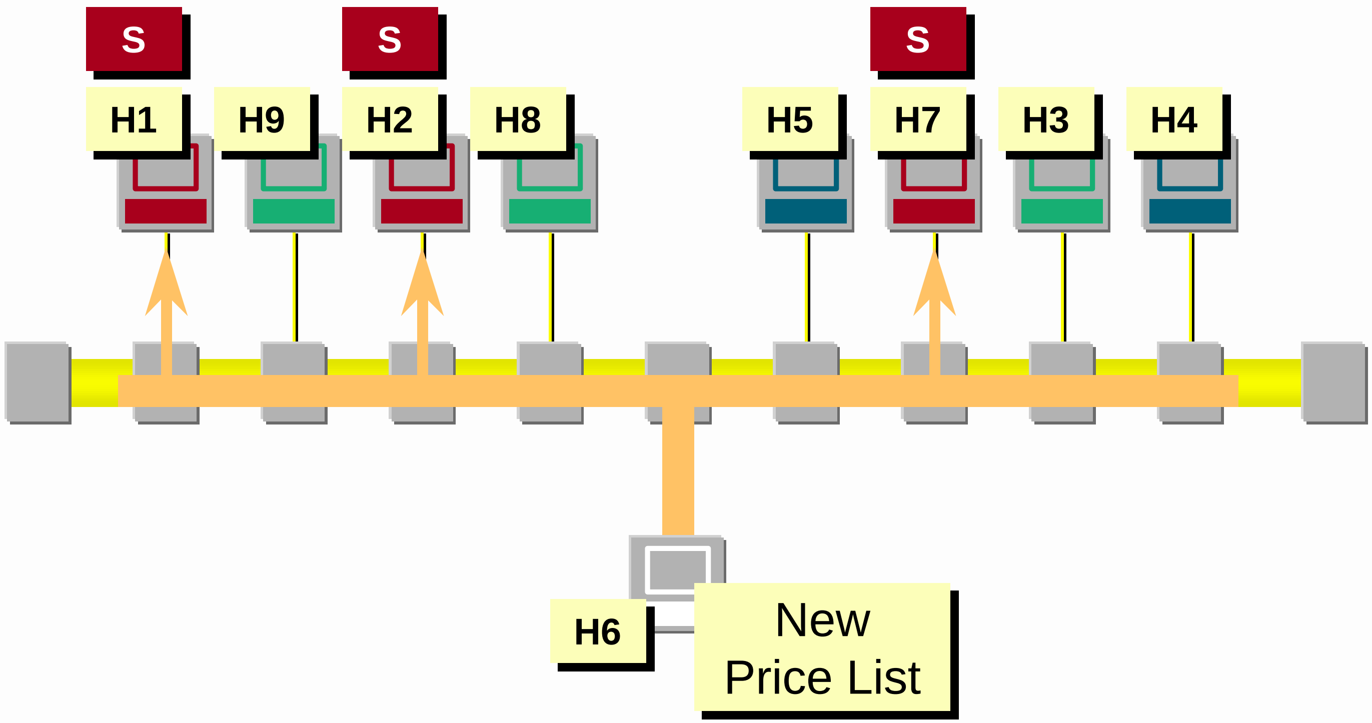
With a broadcast message from the server, the message actually passes by every host on the LAN, and is copied by each NIC...



However, each of the functional groups using the LAN (ie. Sales, Engineering, Admin) can be allocated a multicast address.

The multicast address for the Sales group can, for example, be programmed into the appropriate NICs. Note that each of these "Sales" addresses is identical.

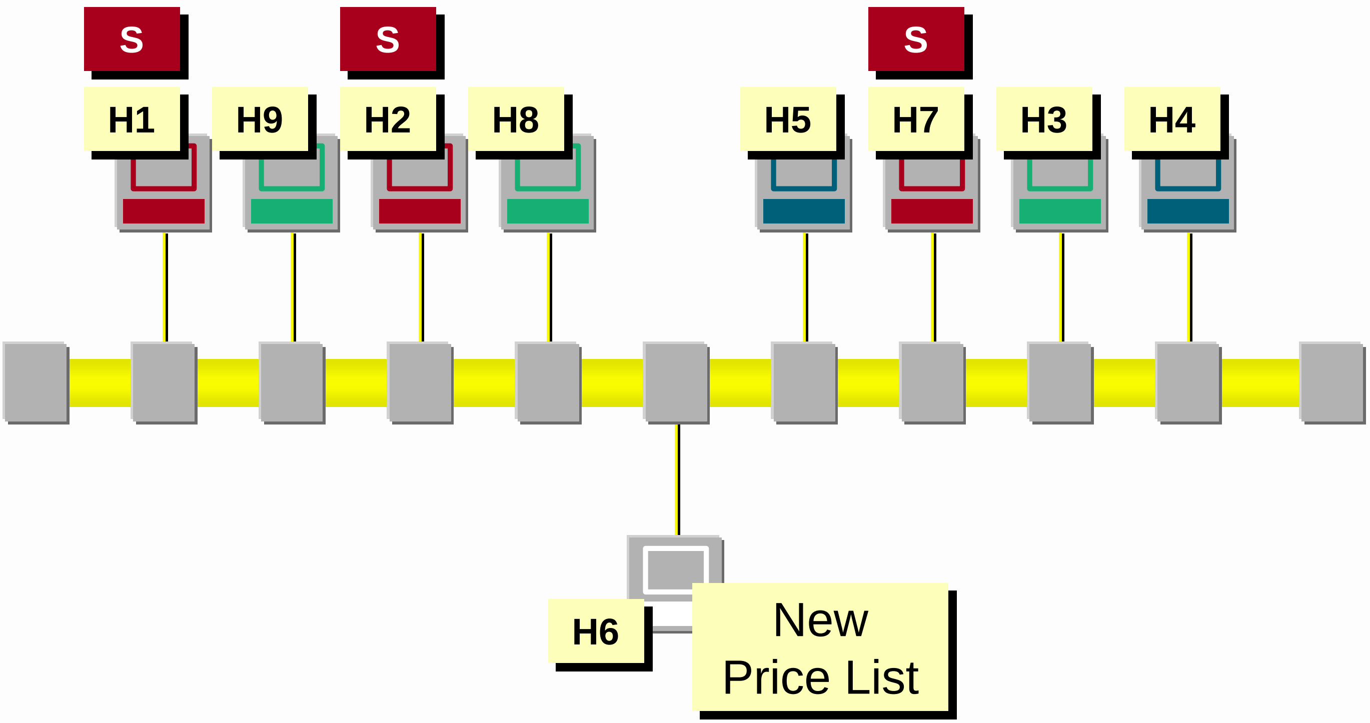
Multicast addresses can also be programmed into the "Admin" (green) and "Engineering" (blue) groups.



As long as the server knows the "Sales" multicast address, then it can send out frames with this multicast address.

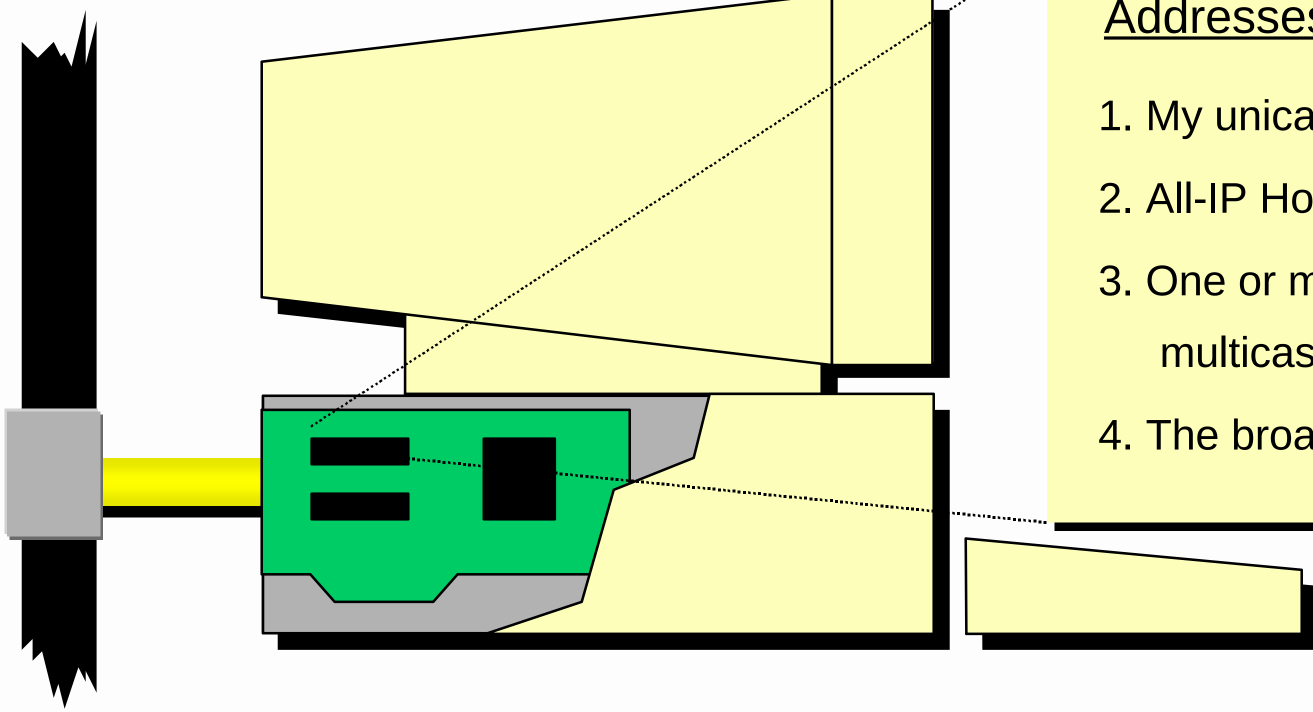
These frames will only be received by NICs that are programmed with the multicast address.

Protocol stacks such as TCP/IP include a dynamic host multicast registration protocol (IGMP for TCP/IP).



So multicasting allows a "private" transmission to controlled groups of destinations.

The membership mechanism for multicasts is that the multicast MAC address is programmed into the NIC. This may be transparent to the user of the PC (for example, a PC running an IP stack should respond to the "all IP Hosts" multicast).



Addresses I Recognise

1. My unicast address
2. All-IP Hosts multicast
3. One or more application multicast addresses
4. The broadcast address

A PC can belong to multiple multicast groups, as well as responding to its unicast address.

As I mentioned earlier, a typical Ethernet adapter can be programmed with up to 8 multicast addresses.

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What are the performance implications of unicast, multicast and broadcast traffic?

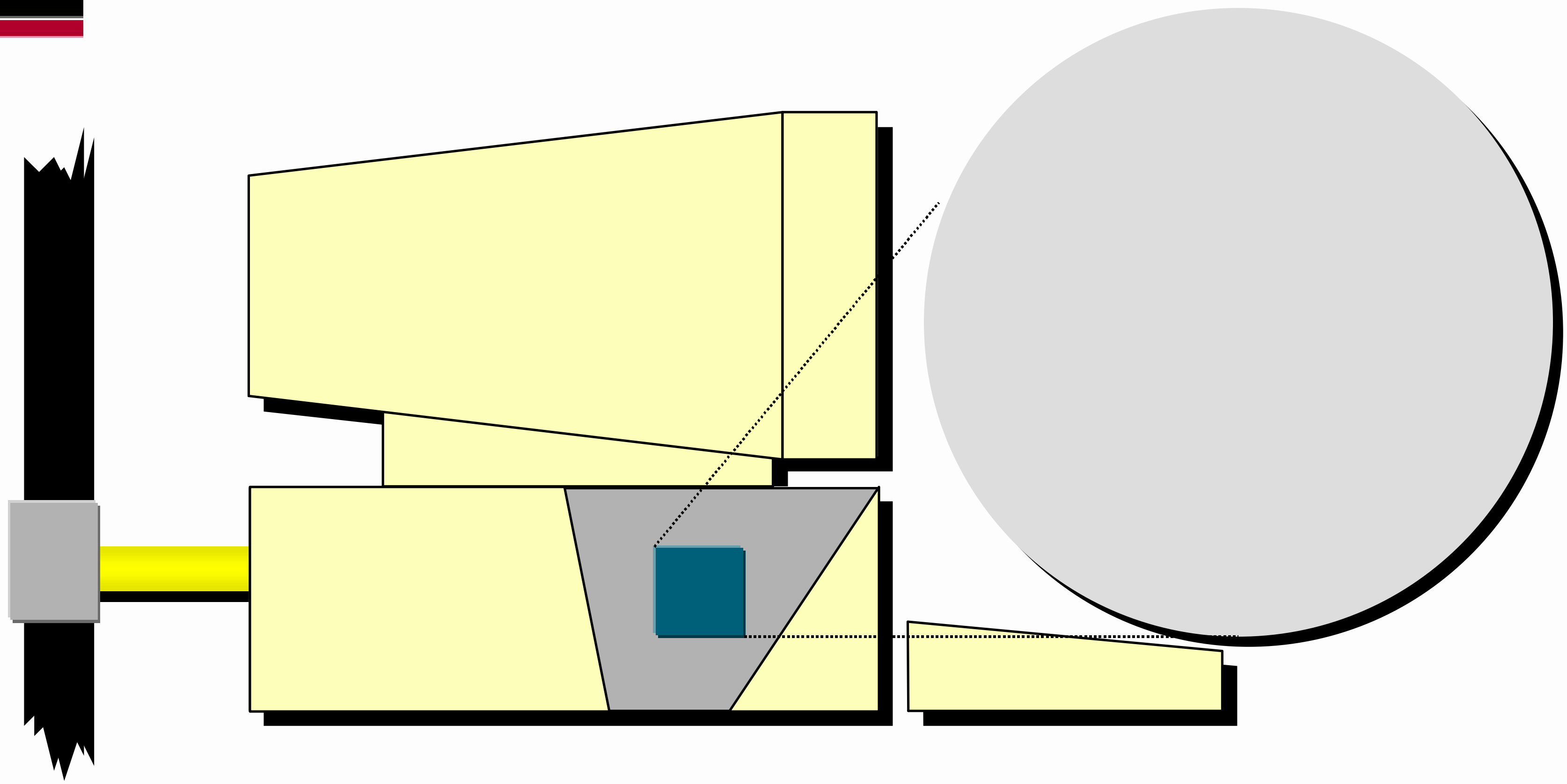
Performance Issues...

- Effects on individual workstation
- Effects on LAN segment
- Effects on extended network

In terms of the performance effects of unicast, broadcast and multicast traffic, let's consider three different aspects.

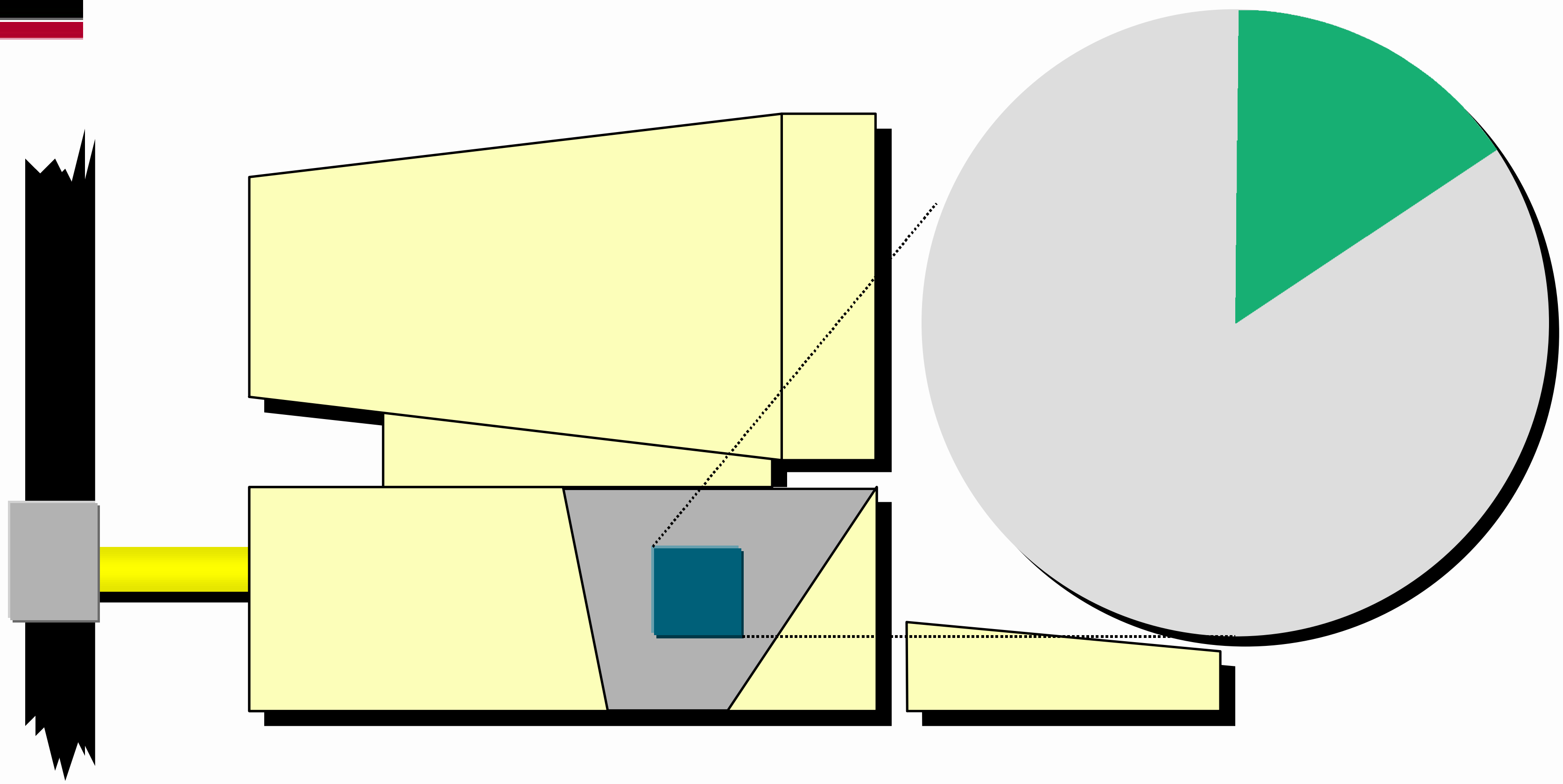
The effect on an individual workstation, the effect on the LAN segment, and finally the effect on the extended network or internetwork.

At the Workstation...

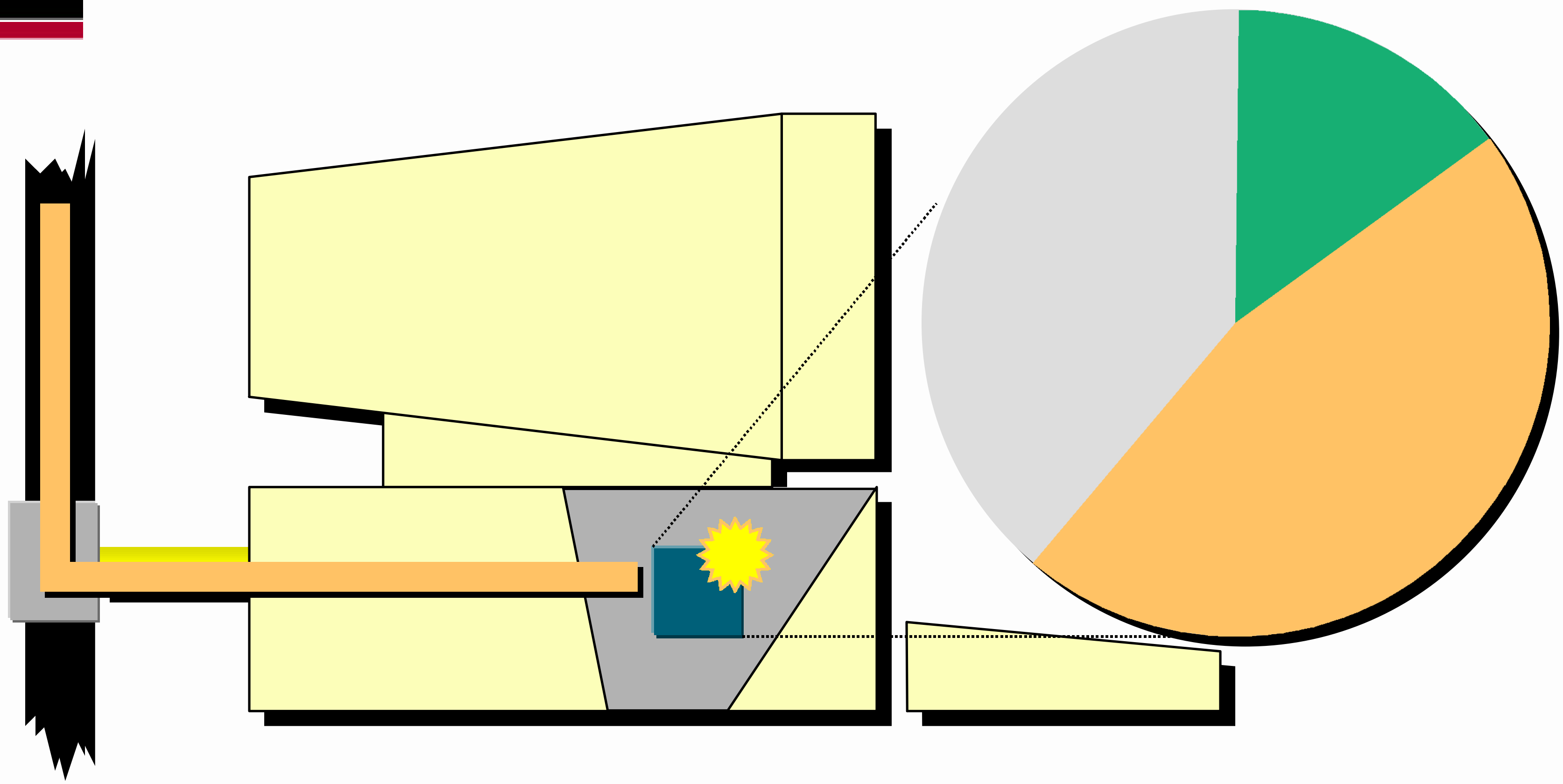


This pie chart represents the total CPU power of a PC.

In theory 100% of this CPU power is available when we switch on the PC.

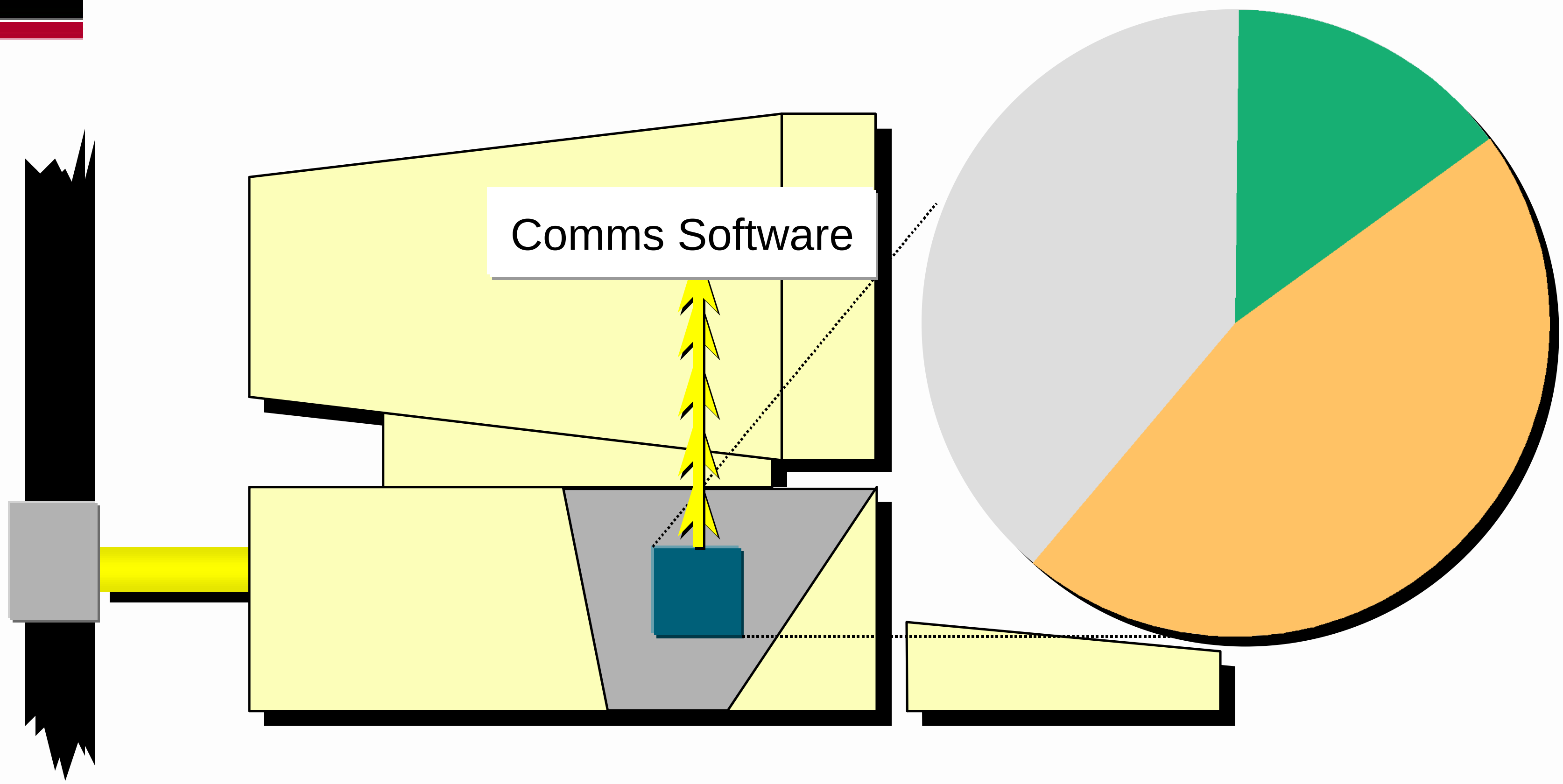


Some percentage of the CPU power is taken up by "housekeeping" duties, represented by the grey portion of the pie.

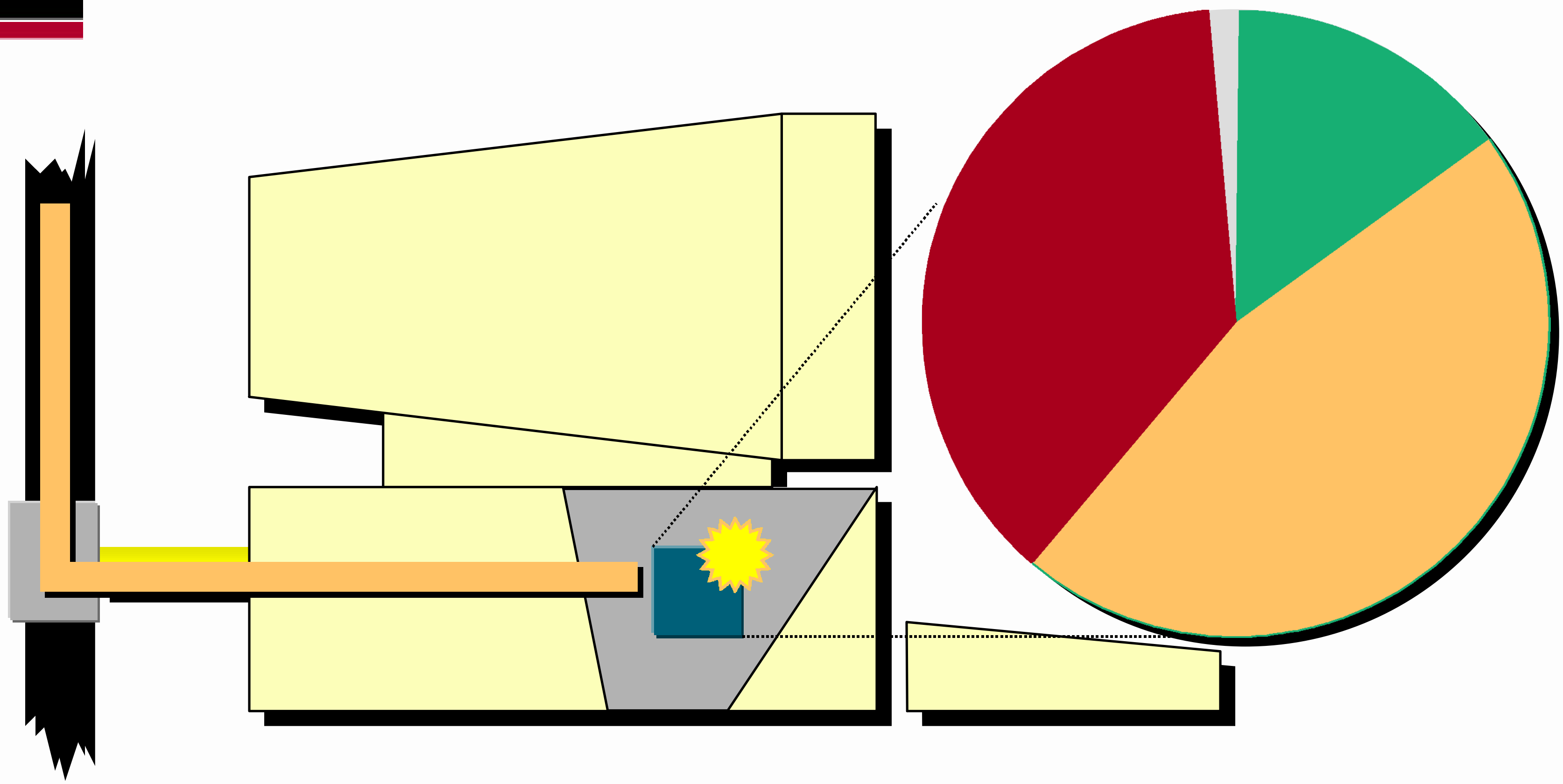


From time to time the PC may receive a burst of LAN transmissions, which means that it's CPU will be interrupted, and its communication software will have some work to do.

Let's say that the gold portion of the pie represents this load.



If the LAN traffic is unicast, or multicast to our multicast group then this load is "well spent" because the message is explicitly addressed to this PC.

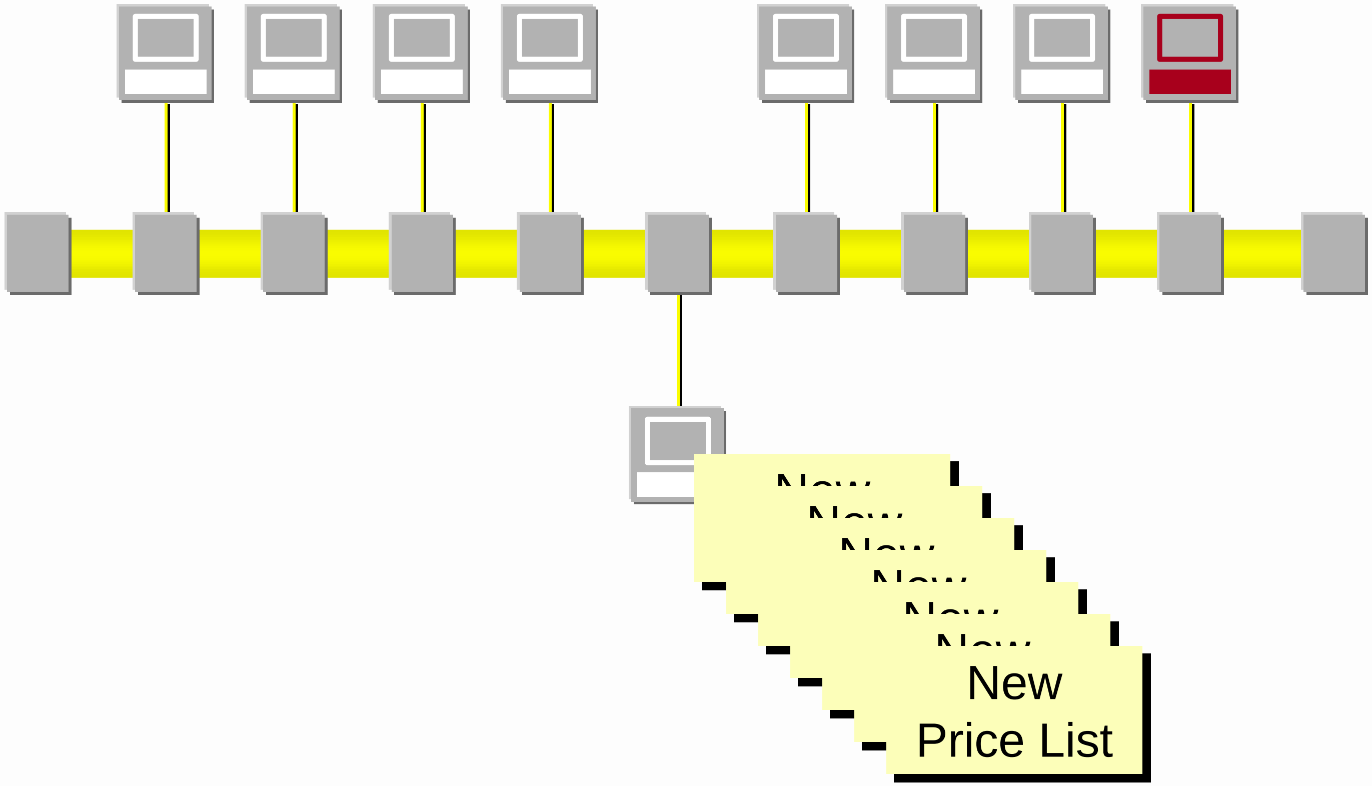


However, if the message is a broadcast, then what are the odds of the frame actually being meant for this PC?

The green and gold portions of the pie chart indicate the percentage of traffic actually addressed to this PC, while the red portion represents the broadcast traffic that has been generated by other members of the LAN segment.

Each of these unwanted broadcasts is sucking CPU power from the PC.

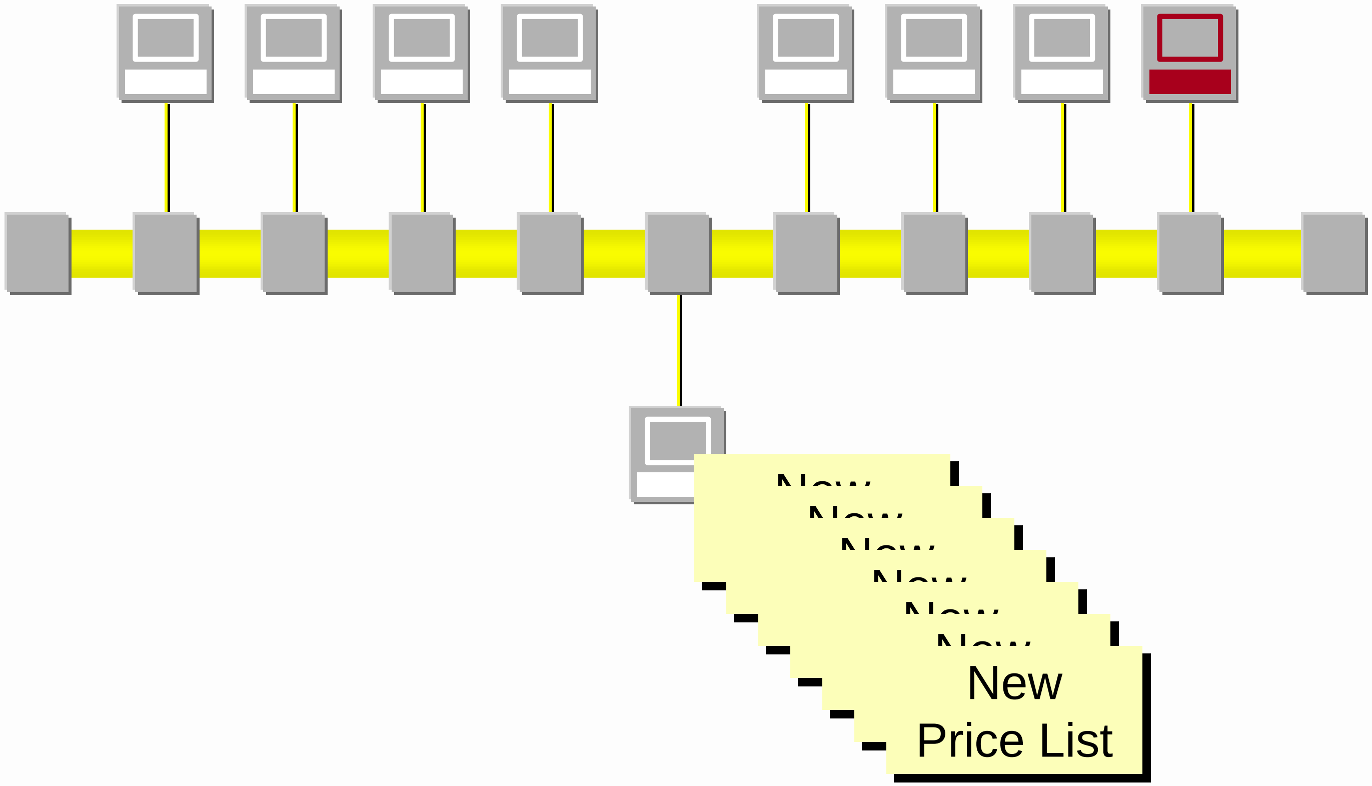
Server Workload…Unicast



Another effect of the kind of traffic on workstation load is the number of packets that need to be sent to transfer the message.

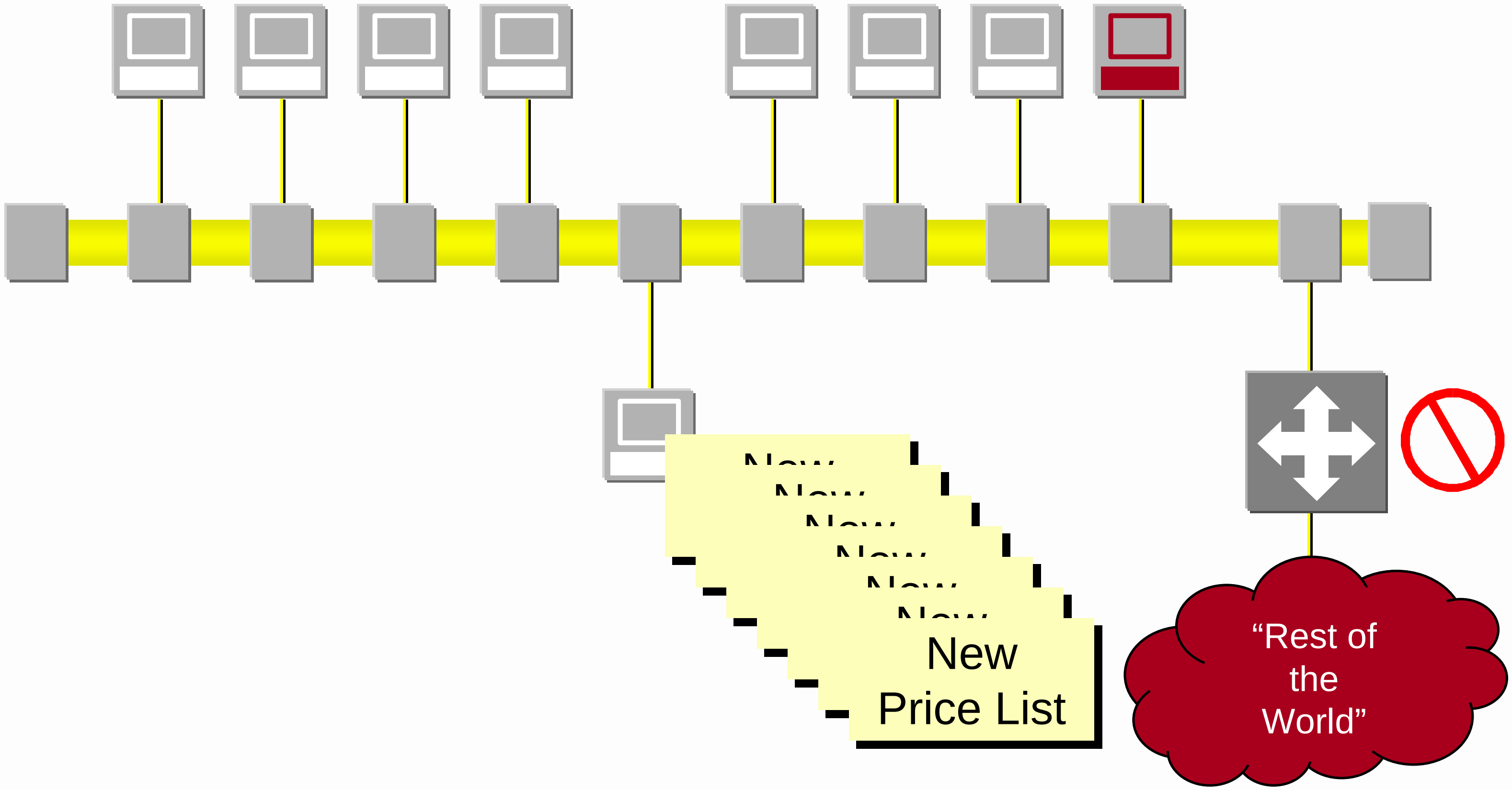
In this example, we have the server ready to send a 1MByte price list update to 7 out of the 8 machines on the LAN segment (ie., to all but the red station).

Segment Workload…Unicast



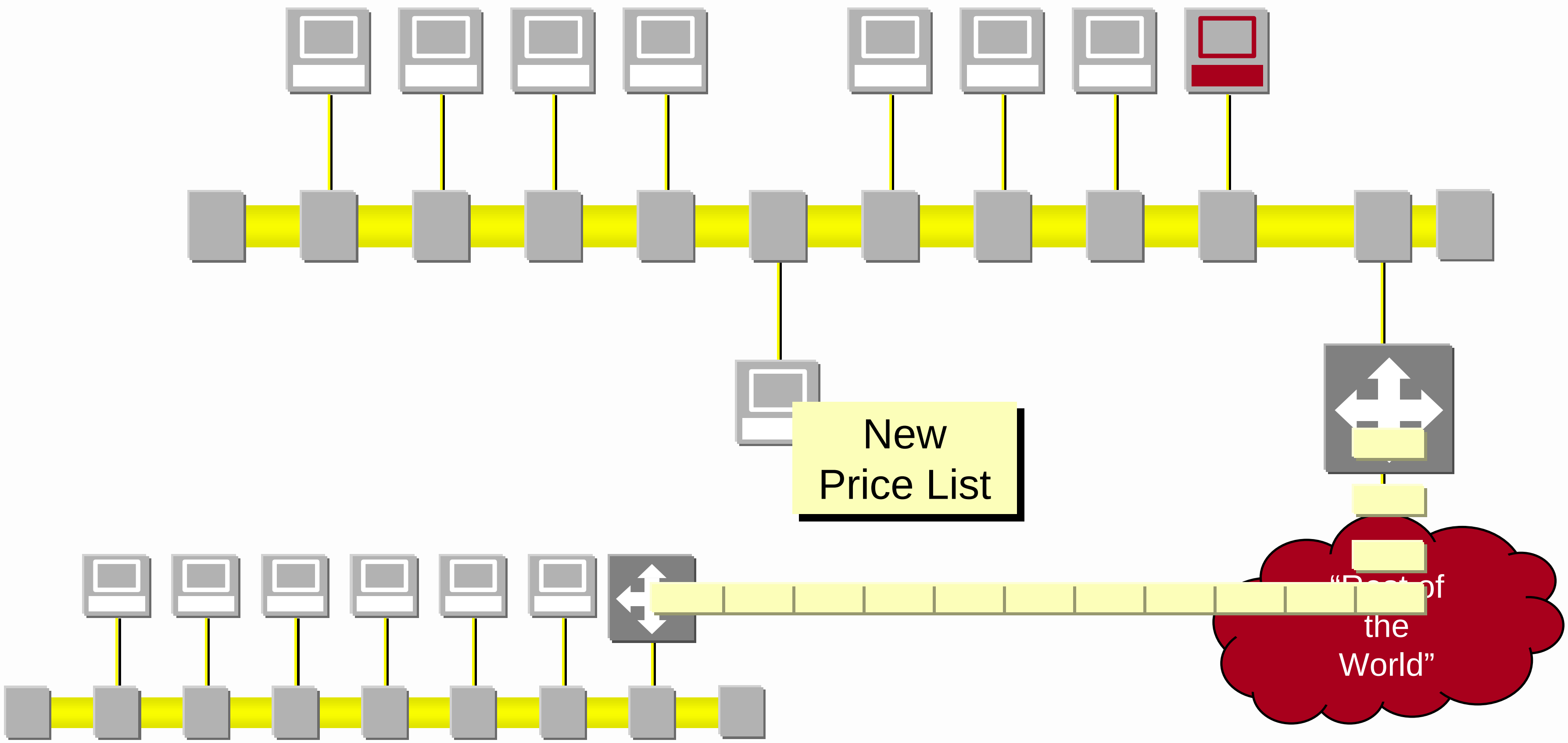
If the server sends unicast frames, it will send the message 7 times, and a total of 7MBytes of information passes over the LAN segment.

WAN Workload…Unicast



If the LAN segment is connected to the rest of the world through a router, unicasts to the 7 workstations will never “leak” onto the bandwidth-restricted WAN.

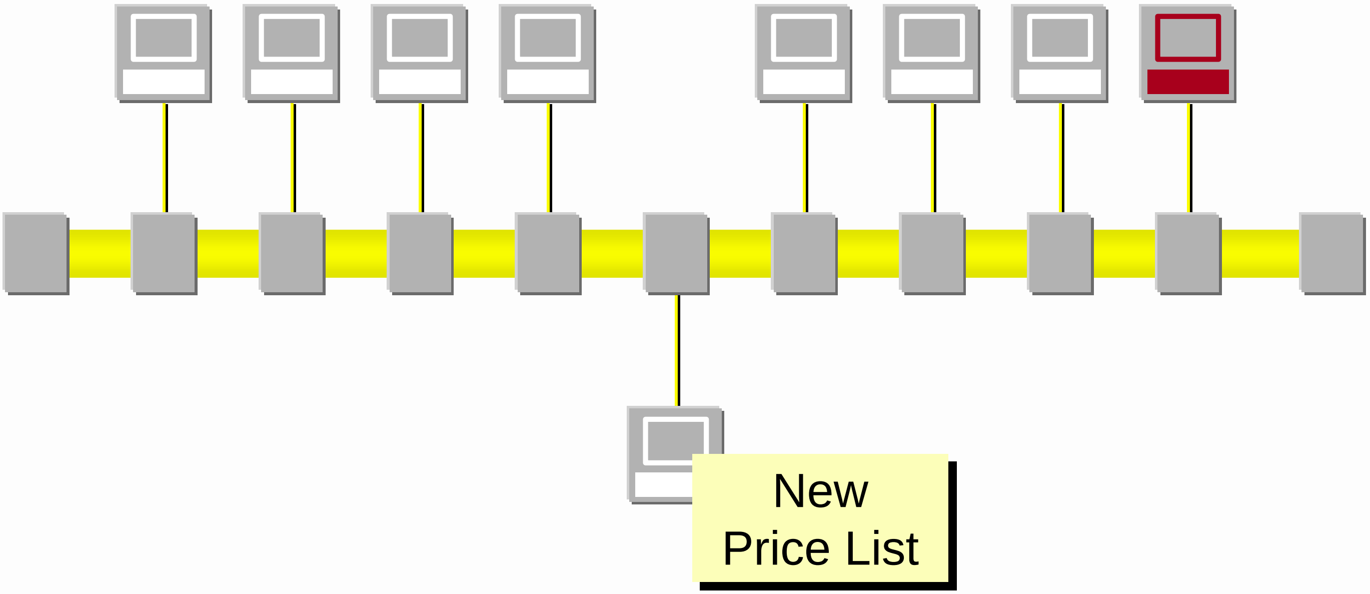
WAN Workload…Unicast



But if there is another set of workstations across the WAN that need to receive the price list update, then an additional copy of the message will have to be sent for each workstation.

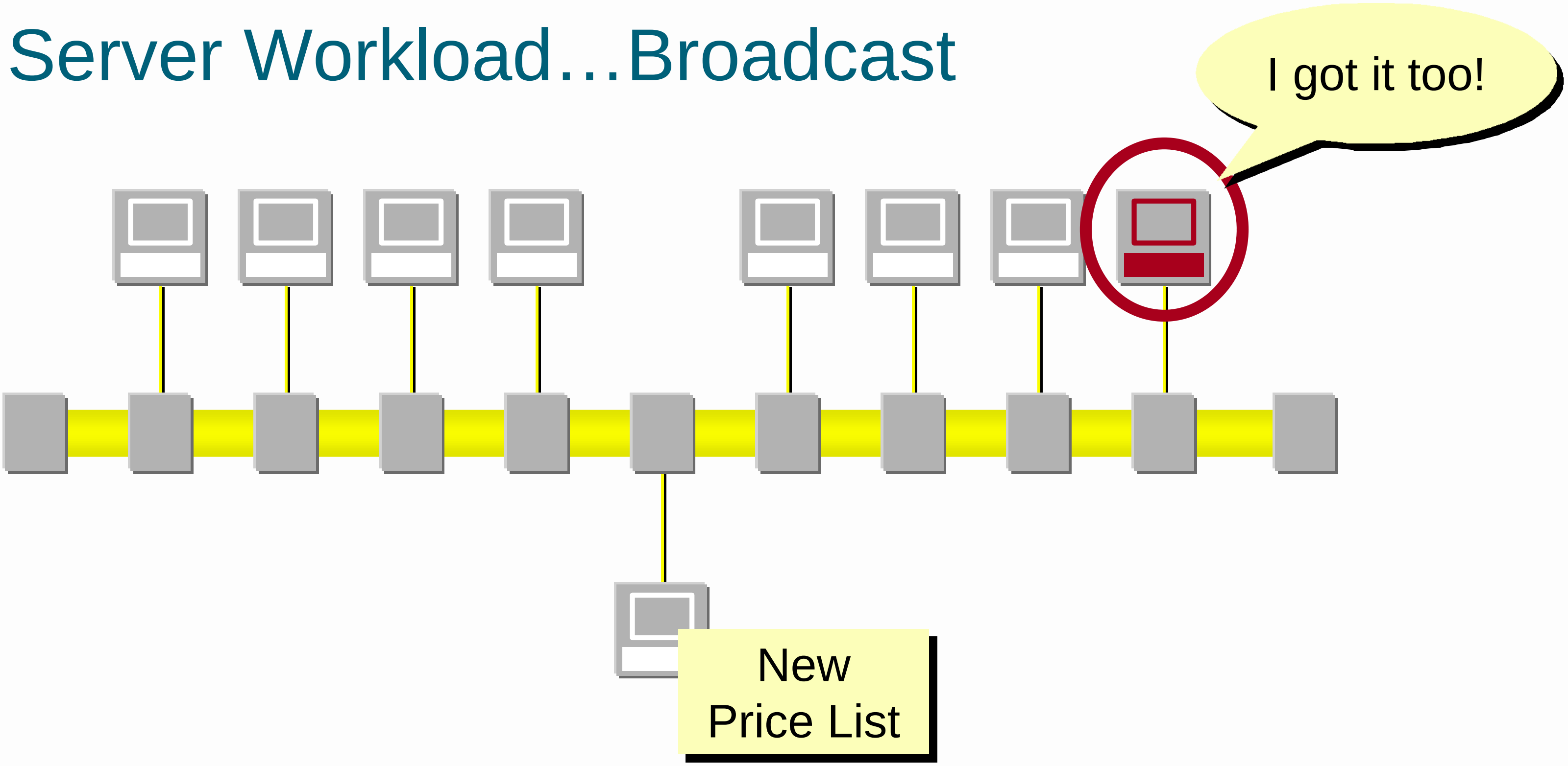
Clearly the multiple unicast mechanism is not a scalable approach.

Server Workload…Broadcast



For a broadcast message the server sends only one copy...

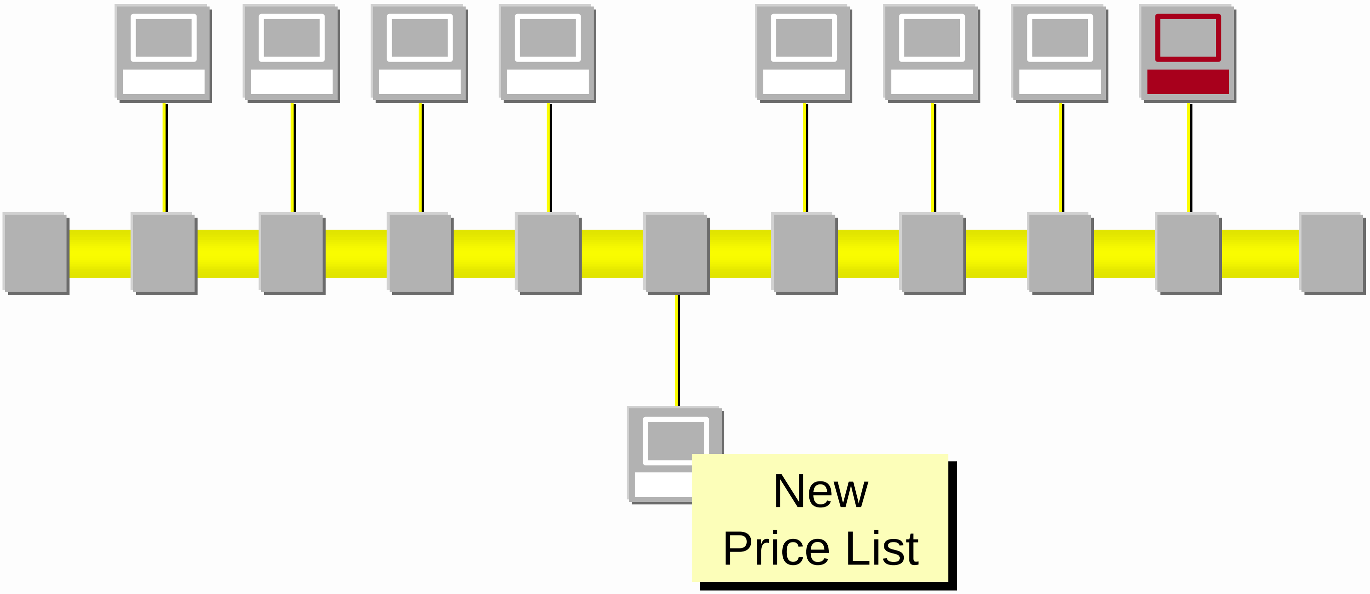
Server Workload…Broadcast



For a broadcast message the server sends only one copy…

…but as I mentioned earlier, every station on the LAN segment will copy the message. At best this places a CPU interrupt burden on the red workstation, at worst it poses a security issue.

Segment Workload…Broadcast

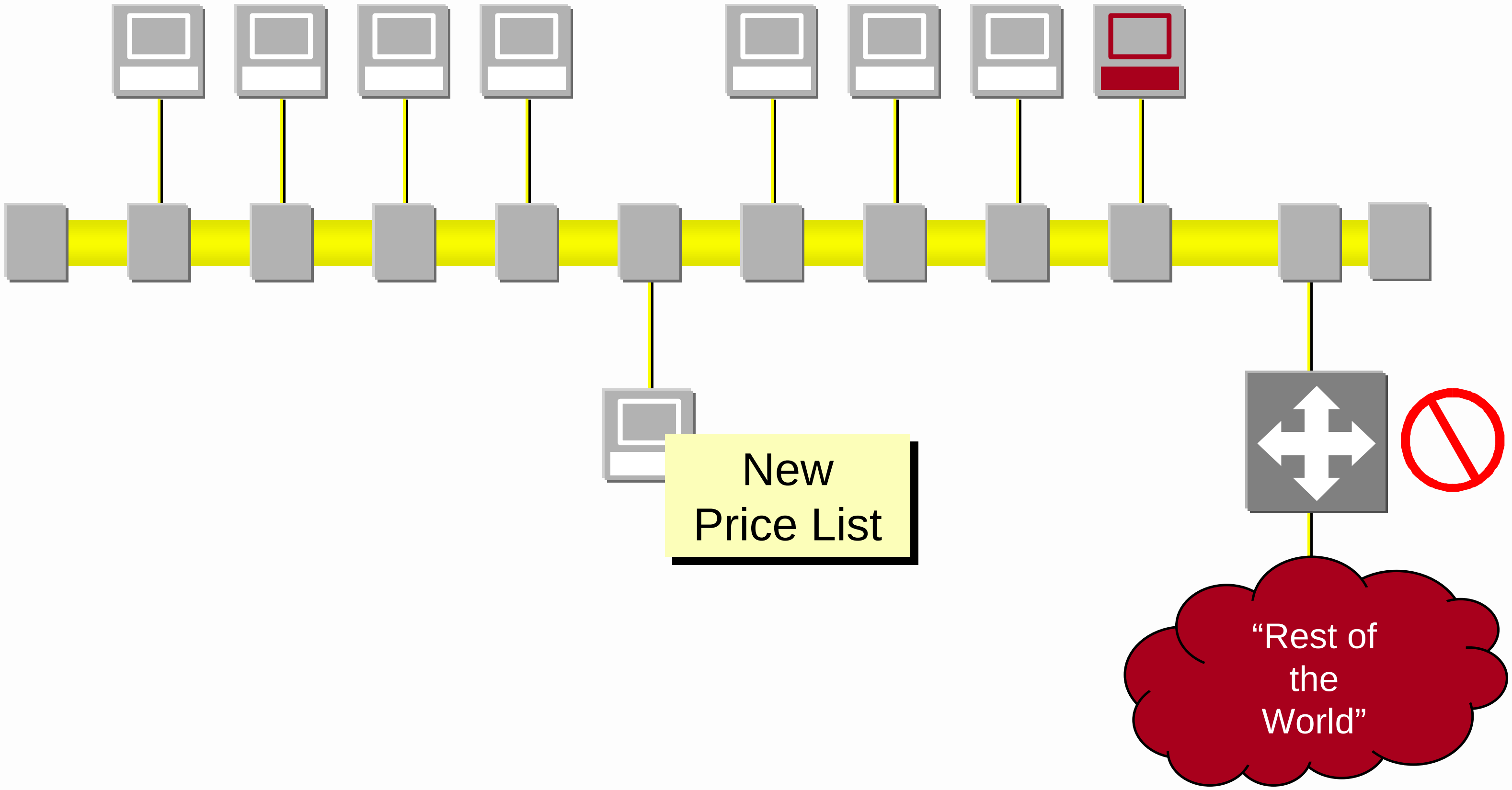


In terms of segment loading, broadcasts are OK because only 1 copy of the message needs to be placed on the segment.

However, if the population of workstations on the LAN segment increases, then the “density” of broadcasts also increases. Since a broadcast MUST be flooded to all members of the LAN segment, there’s no clear mechanism to limit broadcast spread.

FORE SYSTEMS

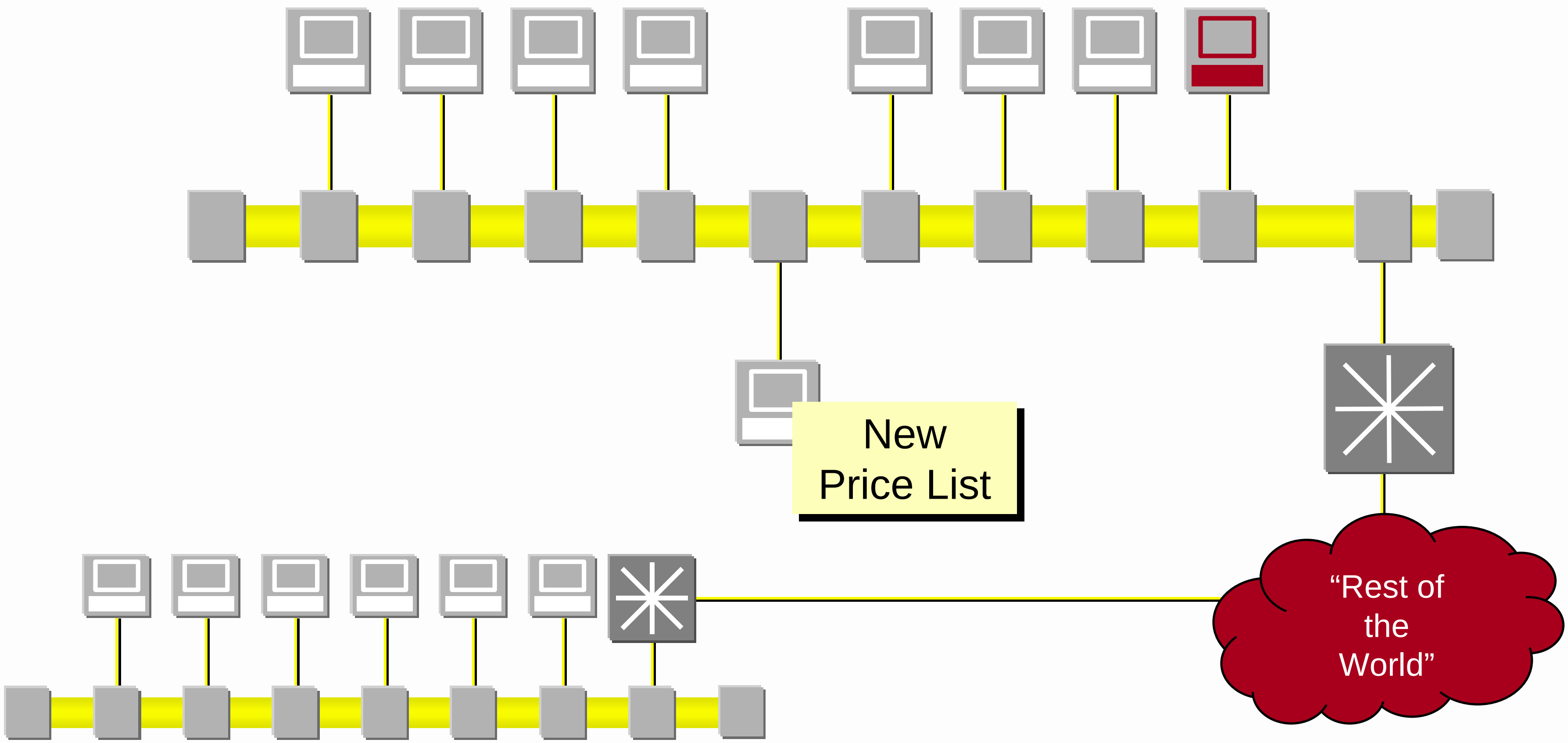
WAN Workload…Broadcast



Strictly speaking, routers MUST block MAC Layer broadcast traffic.

Under certain circumstances, routers may forward, or “process” broadcast traffic. These include the use of Proxy ARP (the router responds to the broadcast), or “all-subnets broadcasts” (this is a Network Layer broadcast which can be enabled in the router), or NetBIOS-over-IP (where broadcast propagation can be contained by filtering on UDP port numbers).

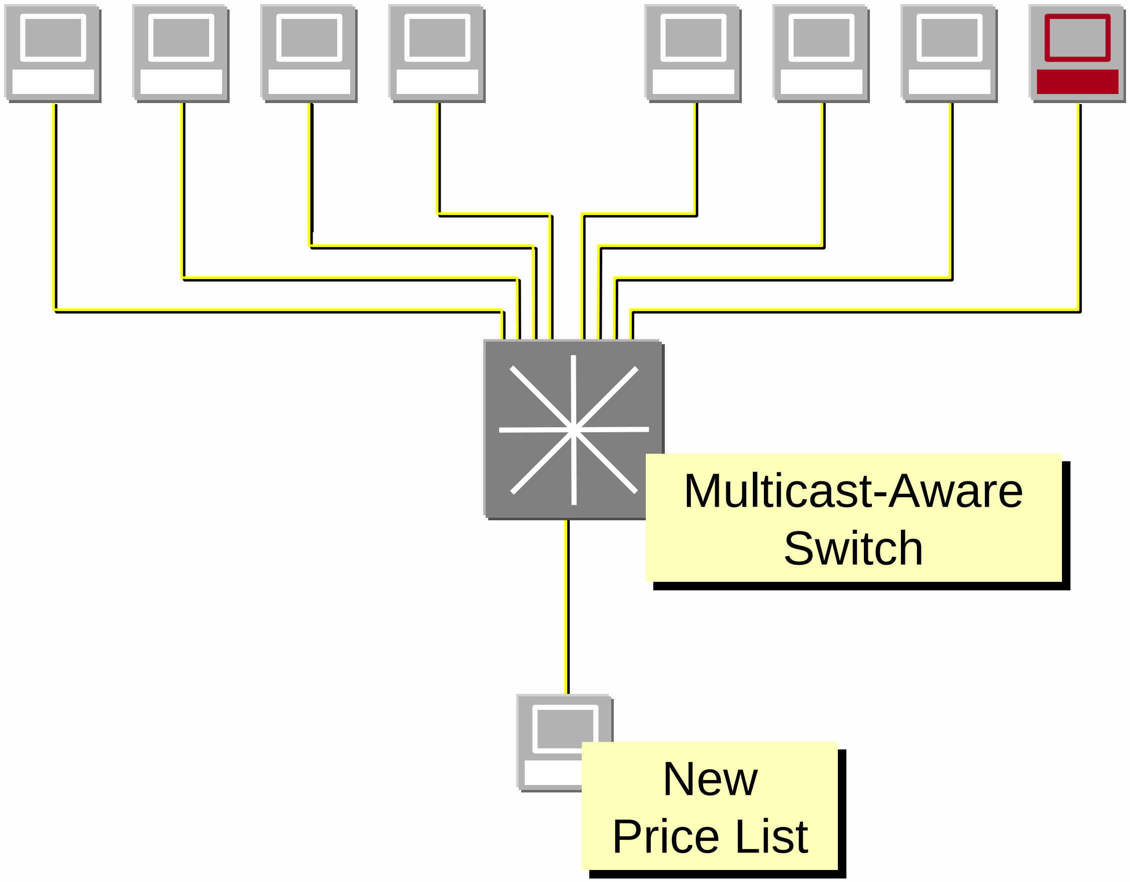
WAN Workload…VLAN Broadcasting



An interesting exception is in the case of extended Virtual LAN (VLAN) architectures.

Since every networking device is now known as a switch (Layer 2 Switch, Layer 3 Switch, etc.), it's fashionable to think about extending VLANs over the WAN. Fashionable, but very dangerous. By extending the MAC Layer broadcast domain, we may end up loading the WAN link with unwanted broadcast traffic.

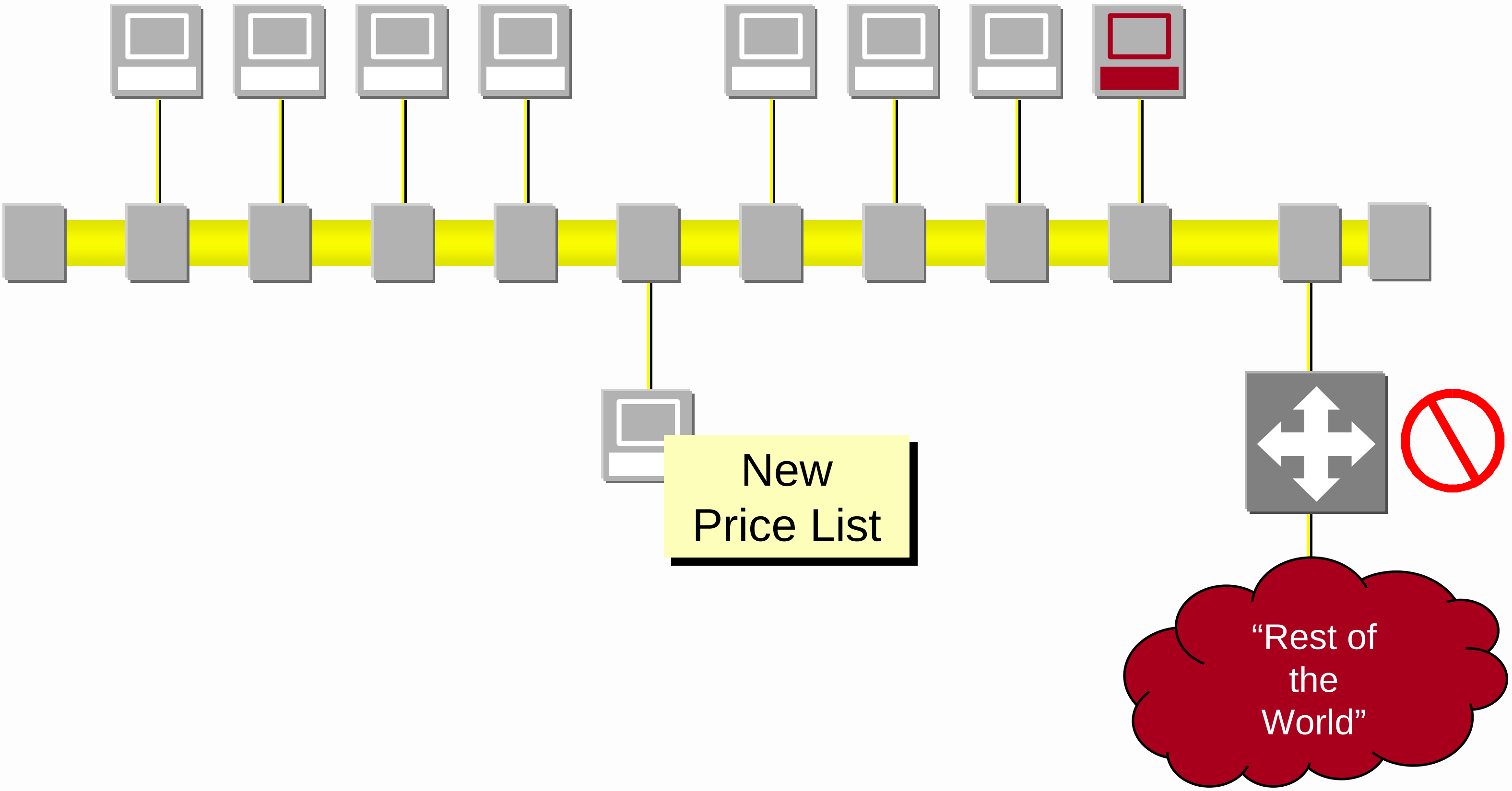
Segment Workload…Multicast



In terms of segment load, multicast is similar to broadcast. However, because each multicast address group is unique, it's possible to design a switch filter to prevent leakage of multicast traffic to links that are not members of the multicast group.

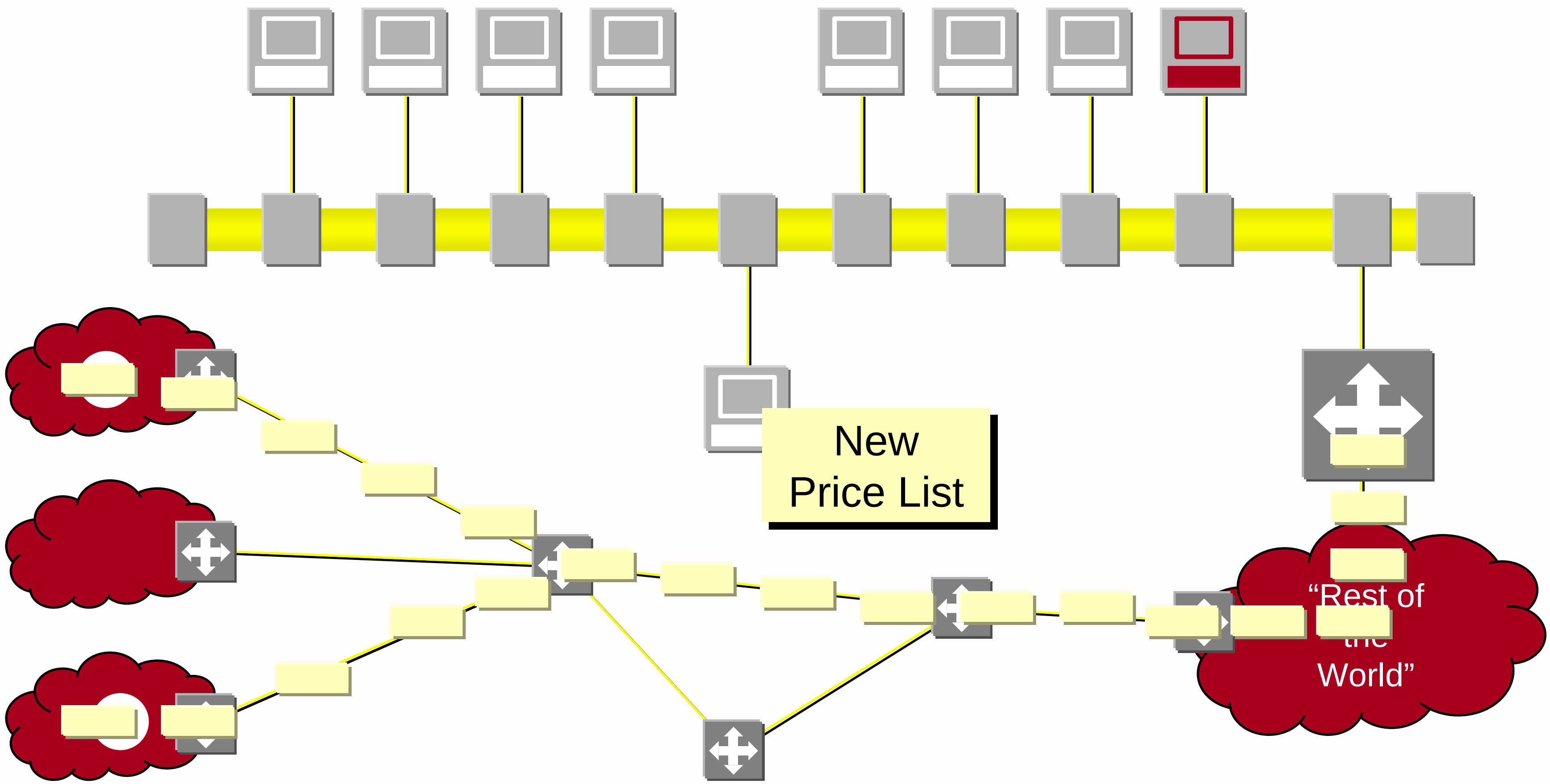
In this example, the new price list update will never actually appear on the link on which the red PC is attached.

WAN Workload…MAC Multicast



In a WAN environment, MAC Layer multicasts, like MAC broadcasts, are automatically filtered.

WAN Workload…IP Multicast



However, if IP multicast traffic is used, then multicast group members can join from anywhere in the network. Once the routers are aware of the multicast topology, they can make intelligent forwarding decisions.

In this example, there are members in the clouds containing white circles who should receive the price list update. Multicast routing will enable a single copy of the message to be sent from the server, and forwarded selectively to the top and bottom clouds, but not to the middle cloud.

Summary of Part 1

- There are three different address types on frame-based LANs
  - Unicast
  - Broadcast
  - Multicast
- Each frame type has a specific use
- Each frame type has an impact on performance
  - Workstation Performance
  - Segment Performance
  - Extended Network Performance

There are three different address formats used on a conventional, frame-based LAN. Unicasts, in which only one end system in the segment will respond to the address. Broadcasts, in which all end systems on the LAN segment will respond to the address. Multicasts, in which selected groups of end systems will respond to the address.

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Each of the frame types has a specific use in the network. Unicasts are used for private conversations between pairs of end systems.

Broadcasts are generally used for the resolution of name or address information, or for status updates (eg. Routing updates, name table updates, etc.).

Multicasts are a more controlled option for status updates, and also have a specific role in terms of multicast application deployment.

Summary of Part 1

- There are three different address types on frame-based LANs
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The use of each frame type has an impact on the overall performance of the system. This impact can be expressed in terms of the effect on the workstation, the effect on the LAN segment and the effect on the extended network.

FORE SYSTEMS

The End

This concludes the tutorial.

If you aren't viewing this tutorial on the FORE Systems' ATM Academy Site, then you can find additional tutorials at:

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