Test #2, Wednesday, April 8

Coverage:	Problem sets 5, 6, 7, and related reading assignments and slides.
Type:	Open book, open notes, an Internet connected computer and/or smartphone with ability to print and scan or take a picture is required. You will be required to be present in a zoom meeting during the testing interval. The test will be made avalable 15 minutes before class. Print it, work it, scan or photograph it, and turn it in by uploading it within a 75 minute period.
Study Aid:	A link to a file of all classroom slides for Test #2 will appear on Canvas.

MIT E-Vent | MIT Emergency Ventilator
Emergency ventilator design toolbox

https://e-vent.mit.edu/

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MIT Emergency Ventilator (E-Vent) Project

MIT E-Vent Unit 002 Undergoing Testing, Image by MD

https://e-vent.mit.edu/wp-content/uploads/2020/03/002-bench-testing-scaled-1.mp4

Some things about Wednesday's class:

"OSI" stands for "Open Systems Interconnection,"
a standard from the "ISO." (International Standardization Orgainization)
https://en.wikipedia.org/wiki/OSI_model

The OSI Model of Network Communications

OSI Model				
Layer		Protocol data unit (PDU)	Function[3]	Examples
Host layers	7. Application	Data	High-level APIs, including resource sharing, remote file access, directory services and virtual terminals	TLS, FTP, HTTP, HTTPS, SMTP, SSH, Telnet
	6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption	CSS, GIF, HTML, XML, JSON
	5. Session		Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes	RPC, SCP, PAP
	4. Transport	Segment (TCP) / Datagram (UDP)	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing	NETBEUI, TCP, UDP
Media layers	3. Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control	AppleTalk, ICMP, IPsec, IPv4, IPv6
	2. Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer	IEEE 802.2, L2TP, LLDP, MAC, PPP
	1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium	DOCSIS, DSL, Ethernet physical layer, ISDN, USB

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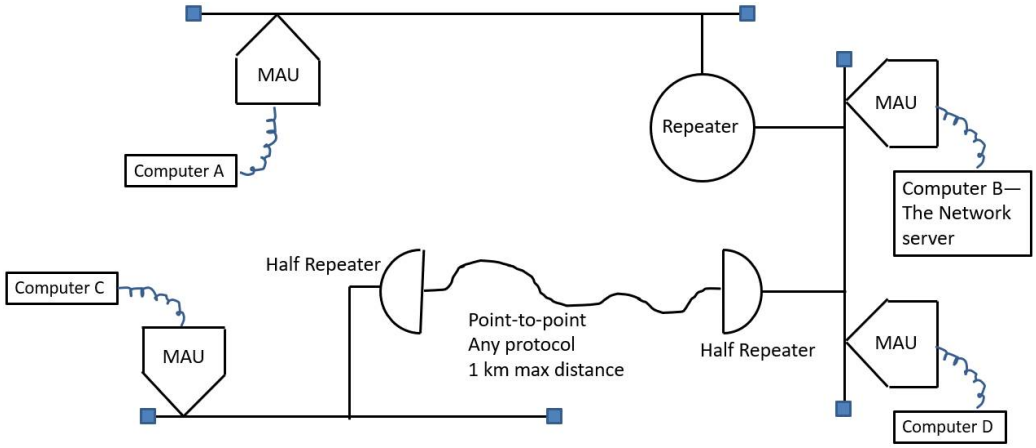
Proper frame length: All collisions detected by all devices on the network.
Computer A finds network is silent.



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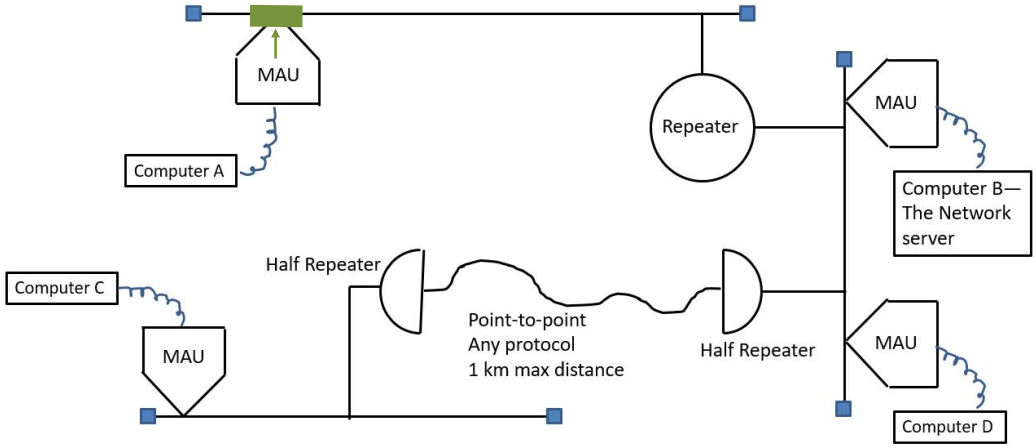
Continues sending—frame propagates.



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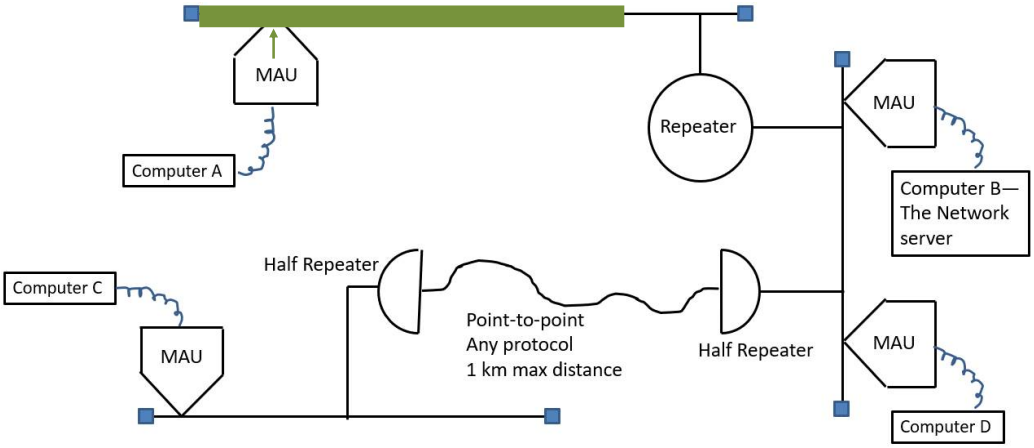

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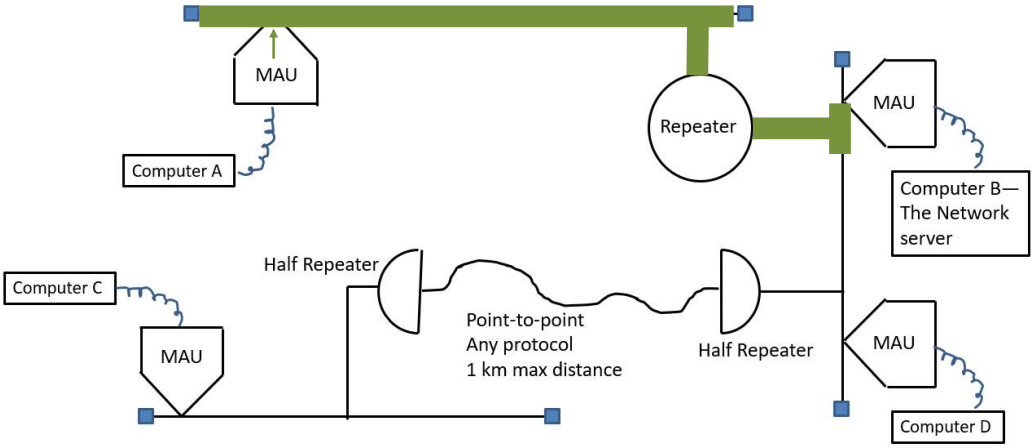
Computer B recognizes that a frame is arriving—starts syncing clock to preamble.



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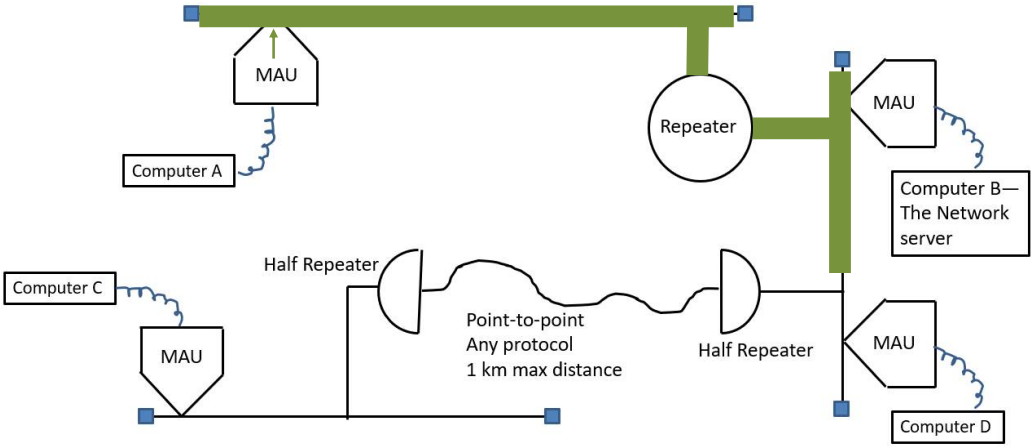
Proper frame length: All collisions detected by all devices on the network.
Computer A continues sending a frame to Computer B ("MA"), the frame propagates.
Computer B is receiving the frame as it continues propagating through the network.



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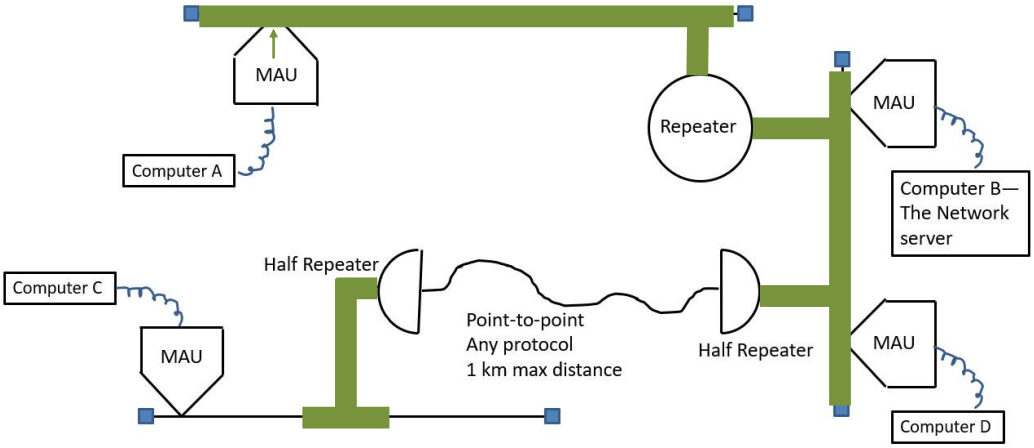

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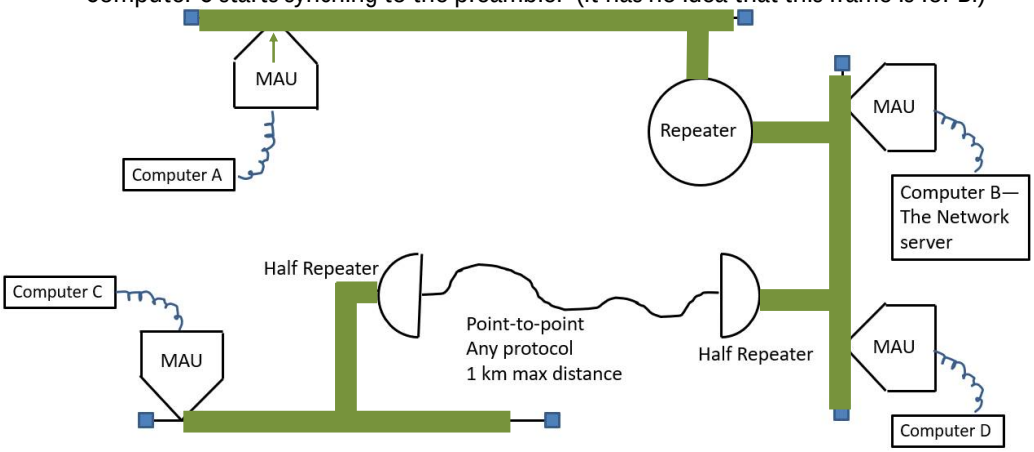
Proper frame length: All collisions detected by all devices on the network.
Computer A continues sending a frame to Computer B ("MA"), the frame propagates.
Computer B is receiving the frame as it continues propagating through the network.
Computer C starts synching to the preamble. (It has no idea that this frame is for B.)



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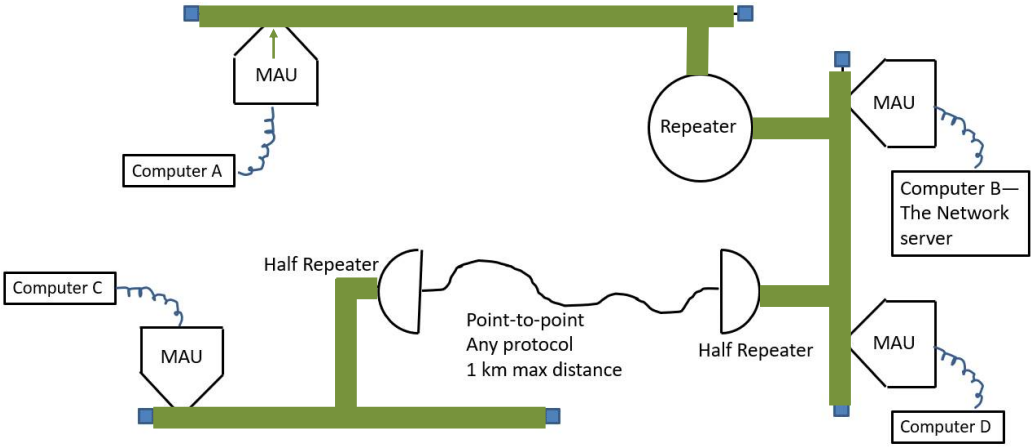
Proper frame length: All collisions detected by all devices on the network.
Computer A continues sending a frame to Computer B ("MA"), the frame propagates.
The frame has now flooded the entire network. Computer A continues sending—to frame end.



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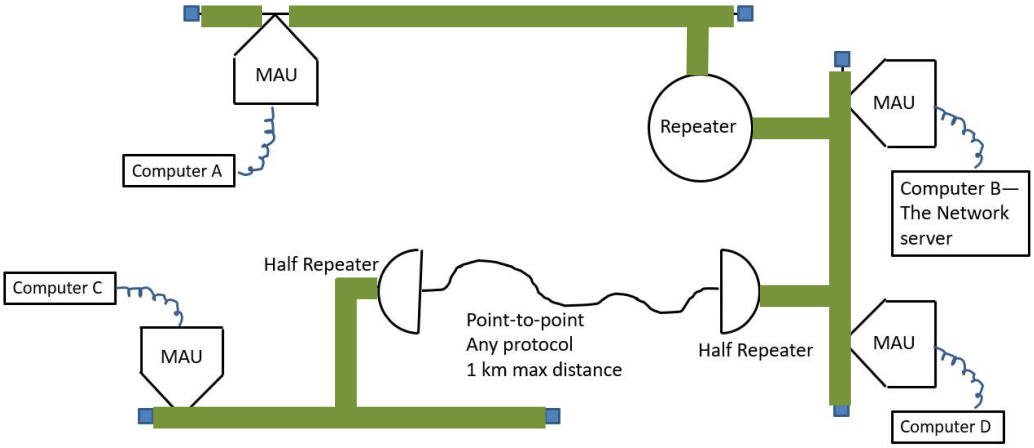
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Computer A has reached the end of the frame and stops sending.
Computers B and C continue scooping up bits of the frame from the Ethernet.



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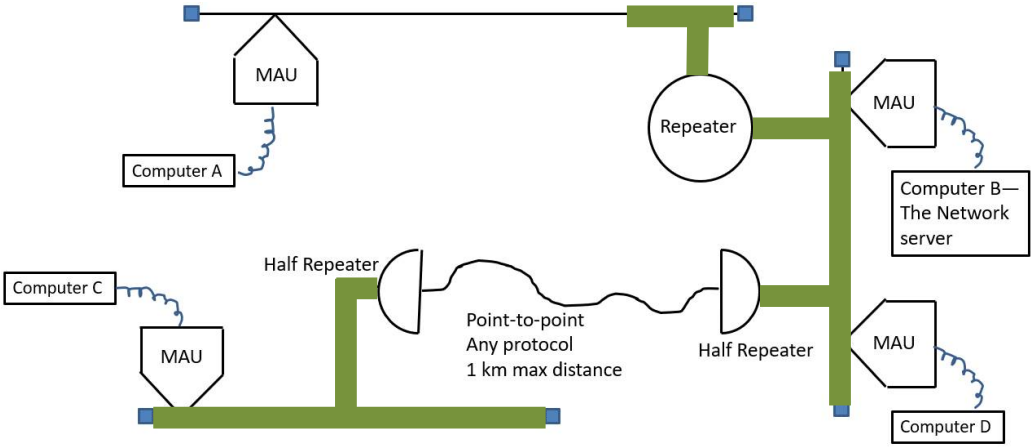
Proper frame length: All collisions detected by all devices on the network.
Computer A has reached the end of the frame and stops sending. Time passes.
Computers B and C continue scooping up bits of the frame from the Ethernet.



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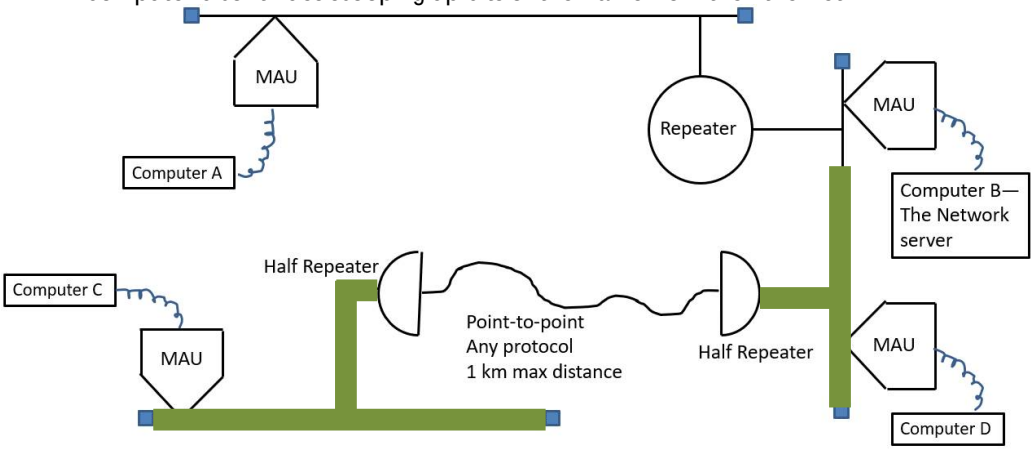
Proper frame length: All collisions detected by all devices on the network.
Computer A has reached the end of the frame and stops sending. Time passes.
Computer B has the entire frame now.
Computer C continues scooping up bits of the frame from the Ethernet.



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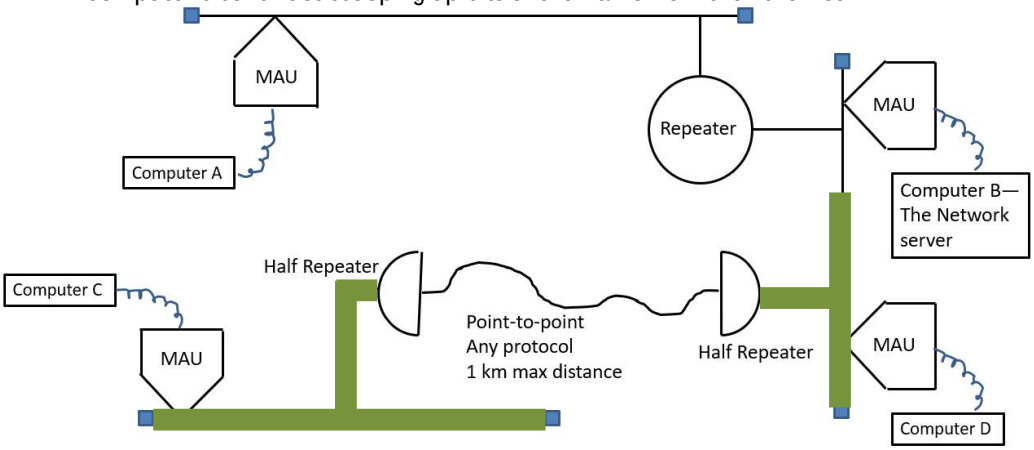
Computer B has the entire frame now.
Computer C continues scooping up bits of the frame from the Ethernet.



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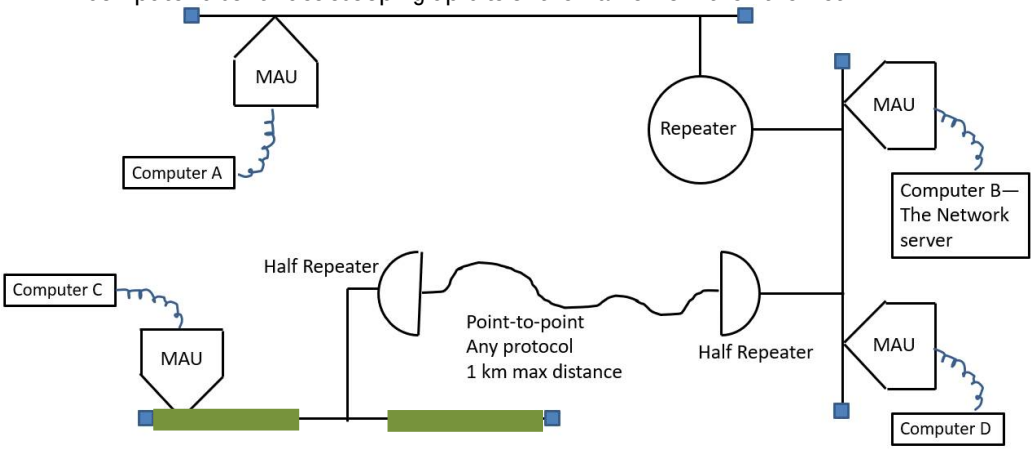
Computer B has the entire frame now.
Computer C continues scooping up bits of the frame from the Ethernet.



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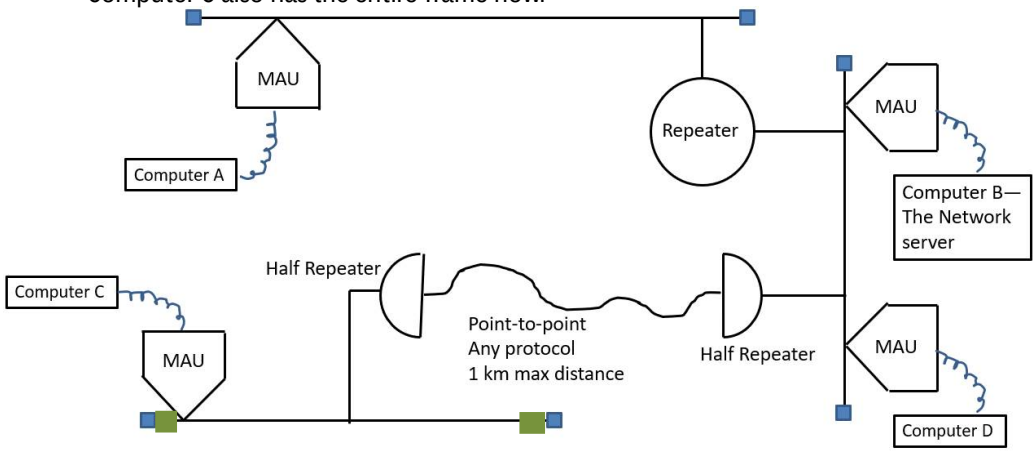
Proper frame length: All collisions detected by all devices on the network.
Computer A has reached the end of the frame and stops sending. Time passes.
Computer B has the entire frame now.
Computer C also has the entire frame now.



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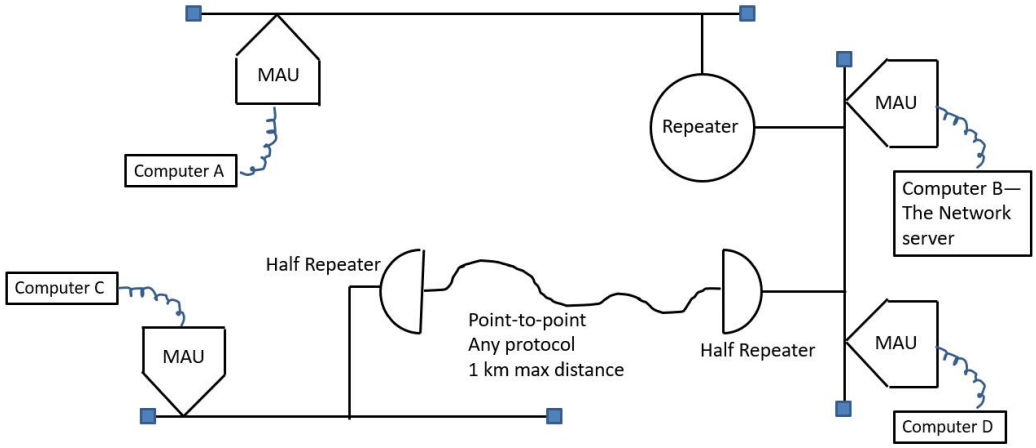
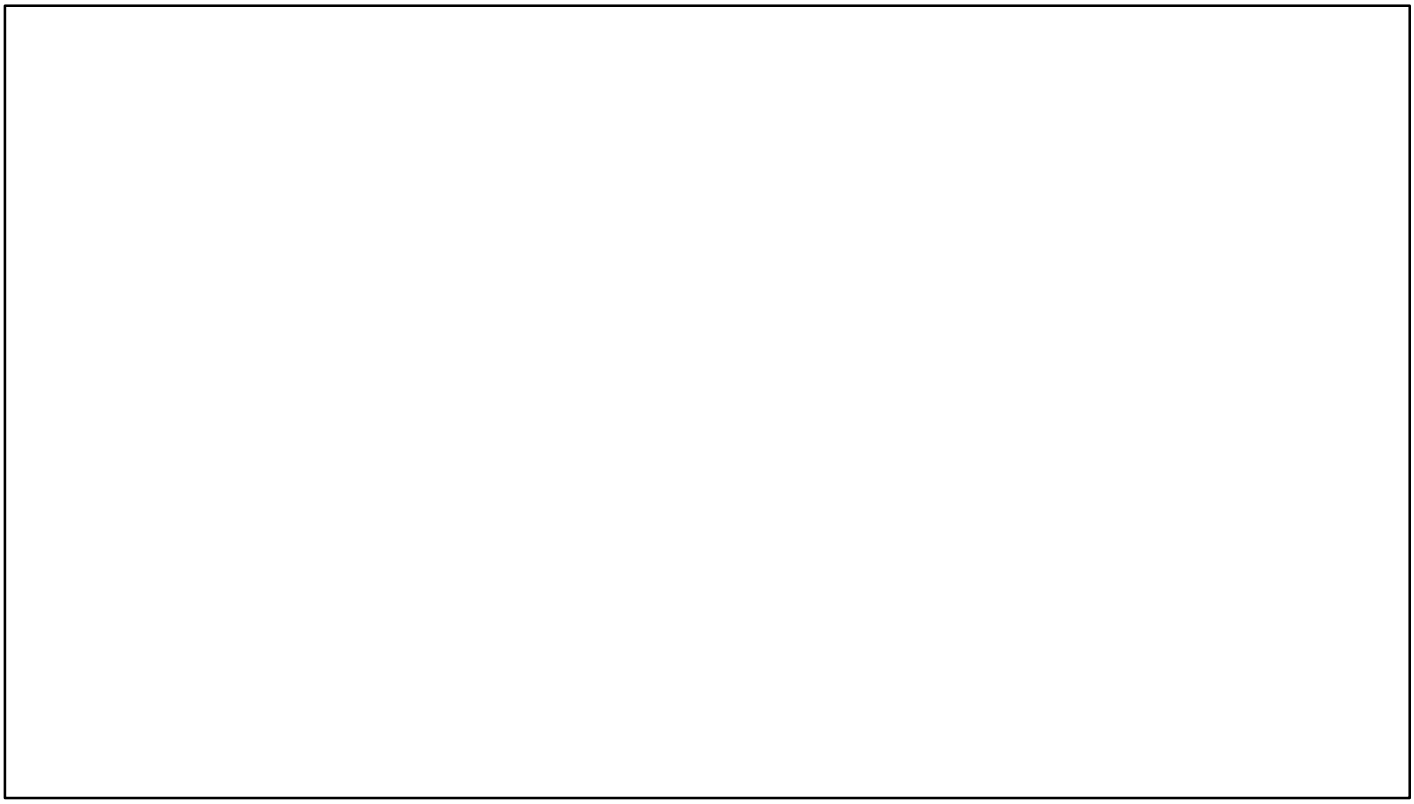
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
It is all over. The entire network is idle again.





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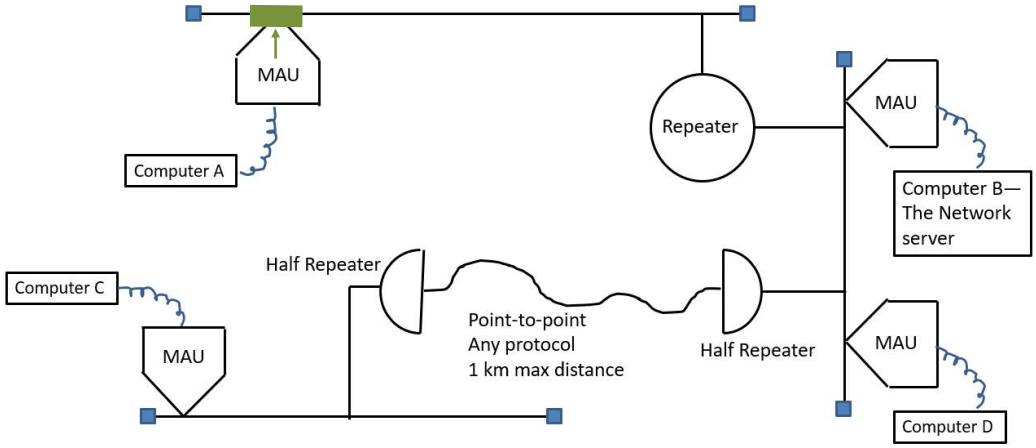
Continues sending—frame propagates.



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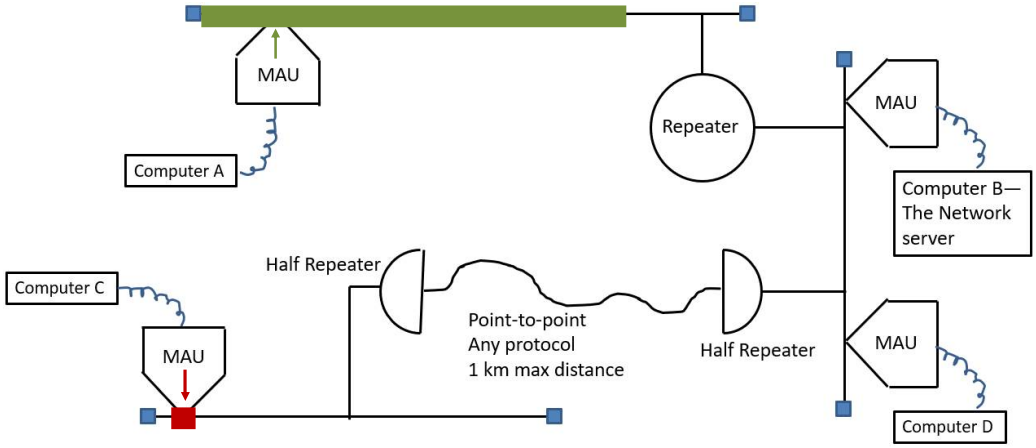
Proper frame length: All collisions detected by all devices on the network.
Computer A continues sending a frame to Computer B ("MA"), the frame propagates.
Meanwhile, Computer C finds the network idle (at its location) and starts sending a frame to D



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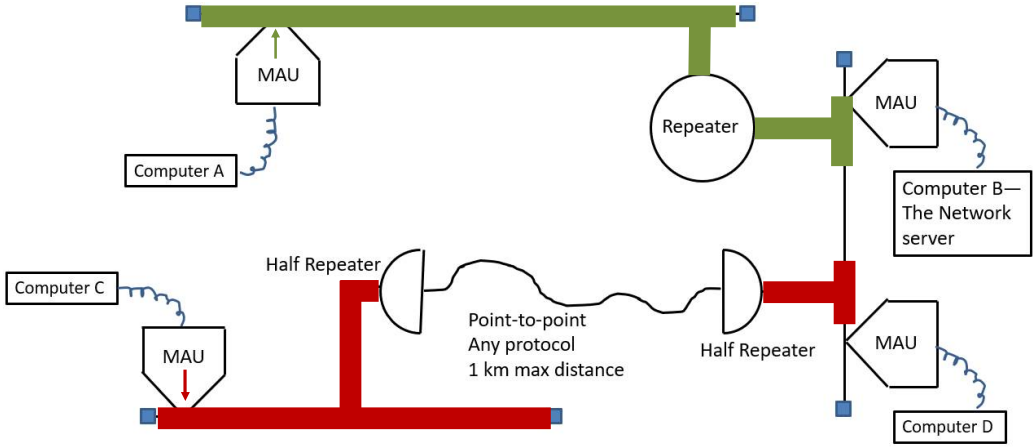
Computer A continues sending a frame to Computer B ("MA"), the frames propagate.
Computer B recognizes that a frame is arriving—starts syncing clock to preamble.



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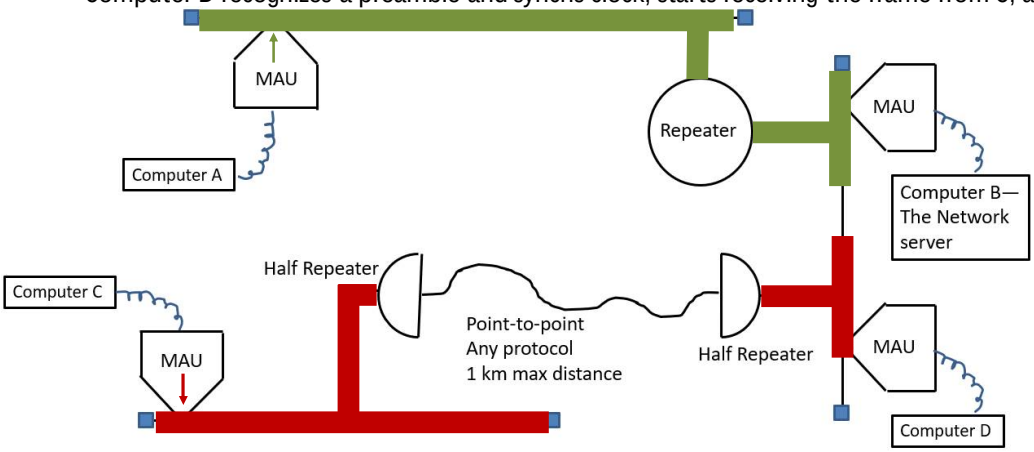
Computer A continues sending a frame to Computer B ("MA"), the frames propagate.
Computer B recognizes that a frame is arriving—starts syncing clock to preamble.
Computer D recognizes a preamble and synchs clock, starts receiving the frame from C, all is good



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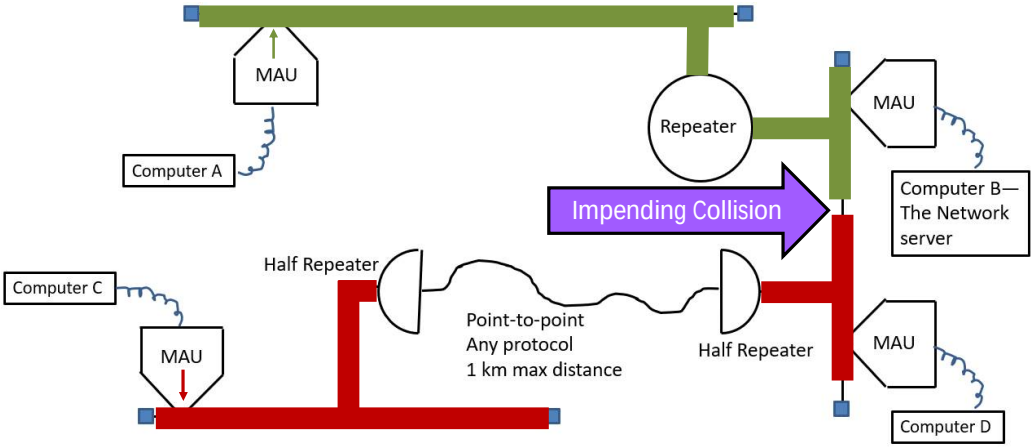
Proper frame length: All collisions detected by all devices on the network.
A collision is about to happen. So far, no harm done.



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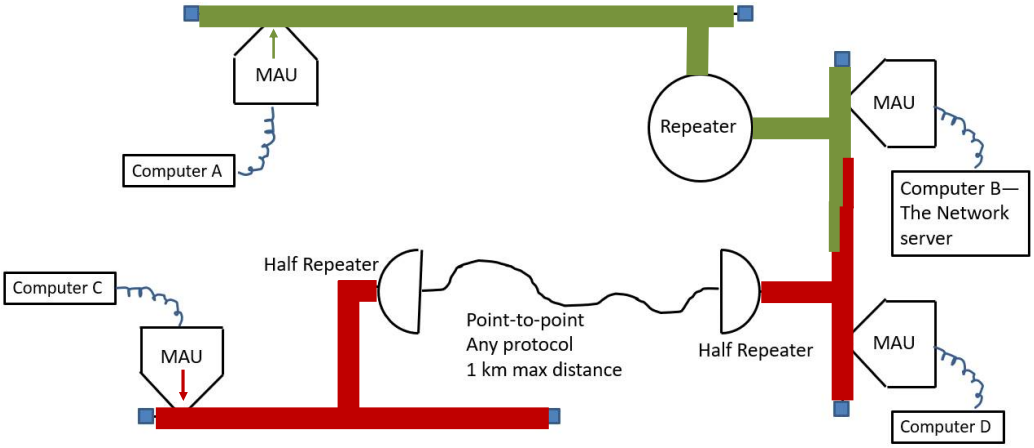
Proper frame length: All collisions detected by all devices on the network.
A collision is in progress. Voltages in the overlapped area superimpose.
Along the length of the collision there are no devices attached—collision is unnoticed, all is good.



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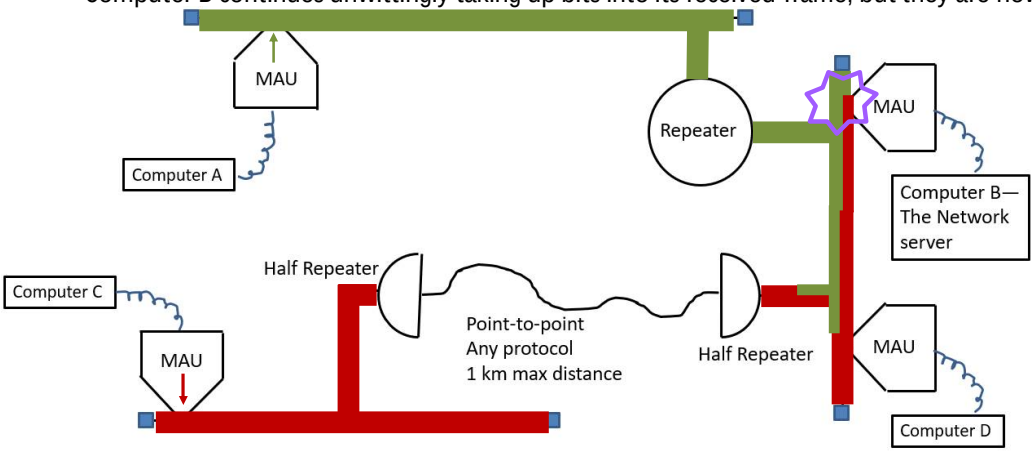
Proper frame length: All collisions detected by all devices on the network.
The collision has propagated to Computer B's MAU.
Computer B is not transmitting. It has no way to detect the collision.
Computer B continues unwittingly taking up bits into its received frame, but they are now garbage.



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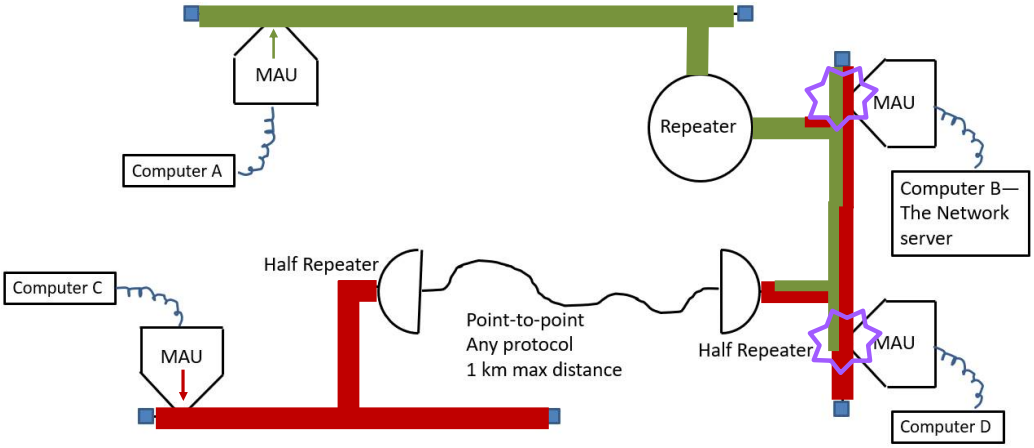
Proper frame length: All collisions detected by all devices on the network.
The collision has reached computer D, which is also not transmitting, thus taking up garbage now.



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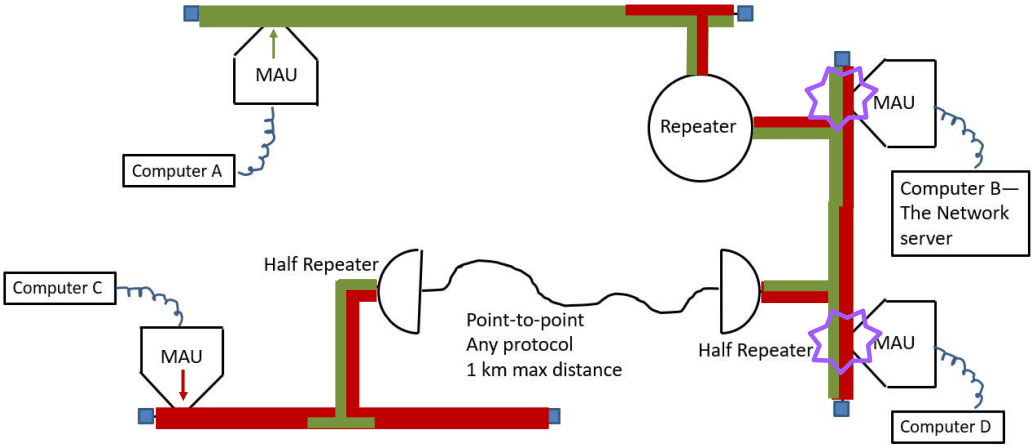
Proper frame length: All collisions detected by all devices on the network.
The collision continues propagating.



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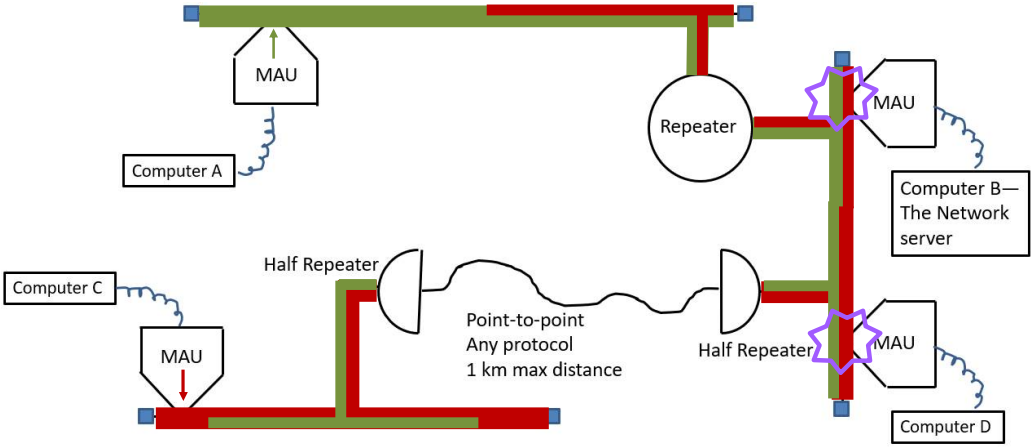

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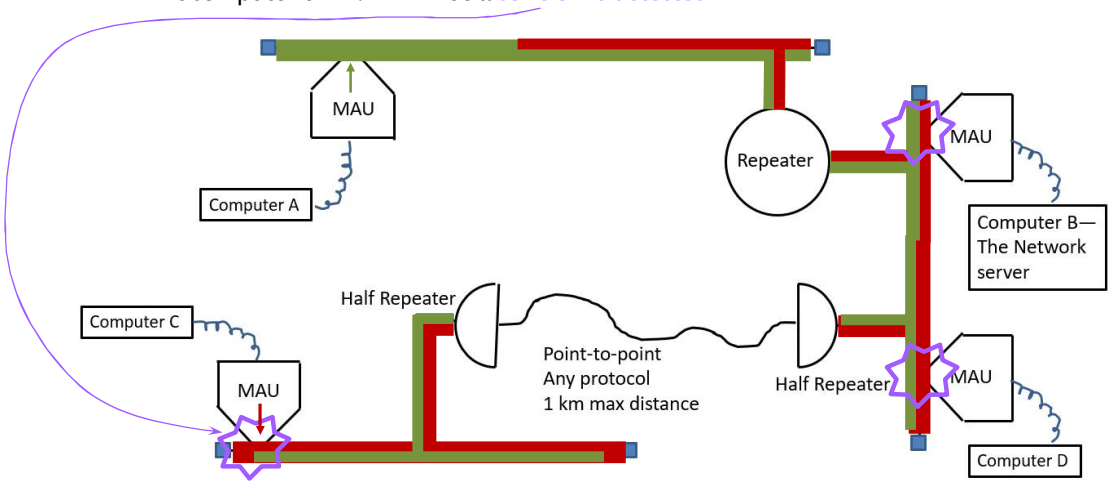
Proper frame length: All collisions detected by all devices on the network.

The collision has reached computer C which up to this point was still streaming out the frame to D.

At computer C Rx ≠ Tx. Thus a collision is detected.



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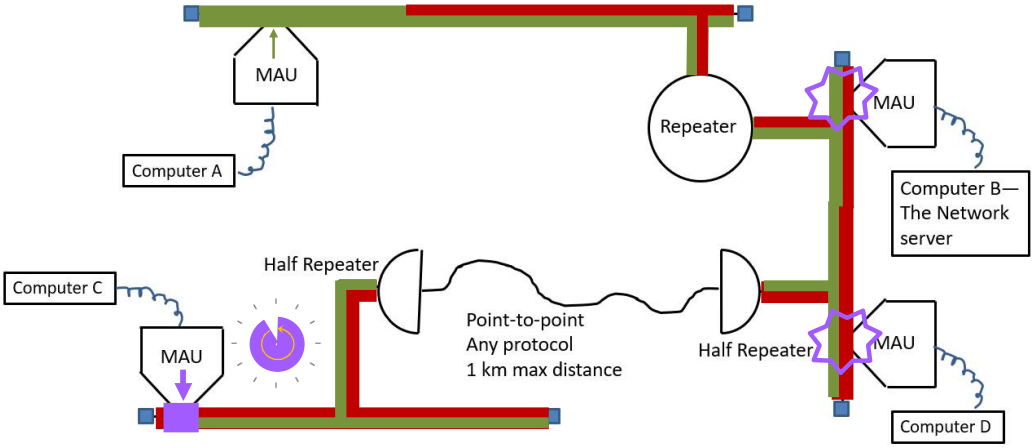
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Computer C abandons sending its frame, increments its collision counter, calculates back-off.
Computer C also starts powerfully sending a collision signal, will flood the network with it. (HONK!)



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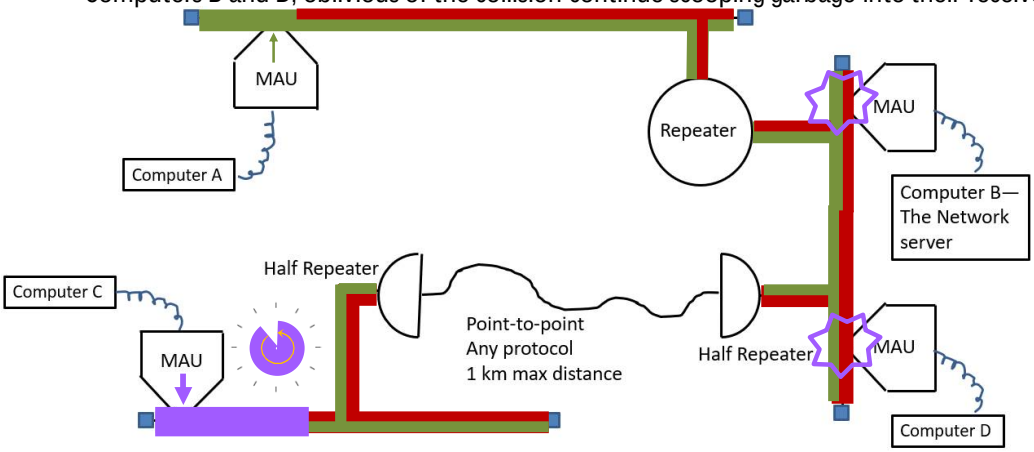
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
All signals continue propagating.
Computer A, oblivious of the collision, continues sending its frame to B.
Computers B and D, oblivious of the collision continue scooping garbage into their received frames.



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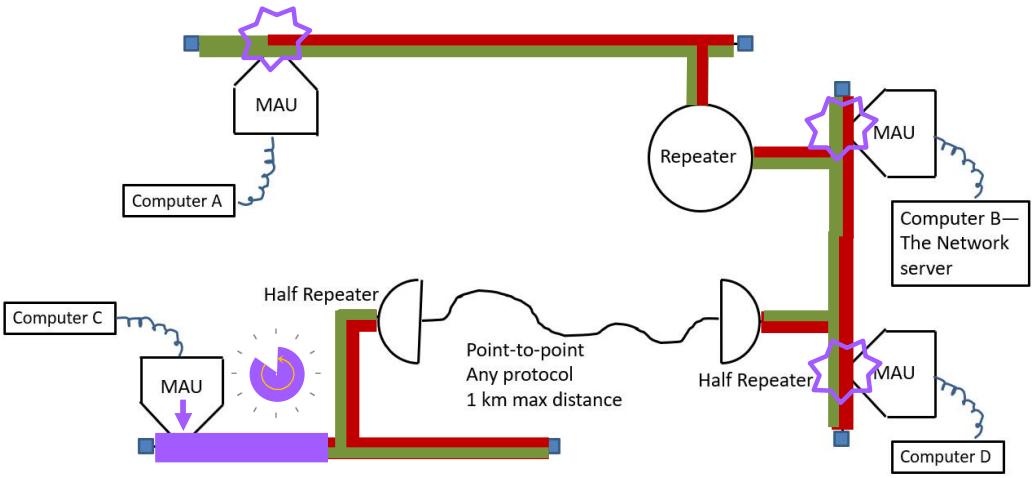
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
The collision reaches Computer A and is detected. Computer A stops sending, computes back-off.



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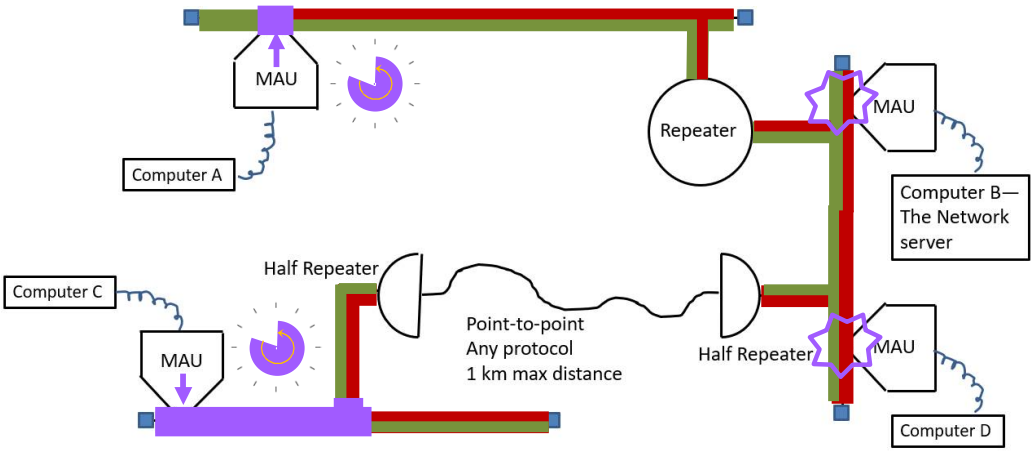
Proper frame length: All collisions detected by all devices on the network.
Computer A emits the collision signal for a long enough duration to flood the network.
It's collision signal starts propagating.



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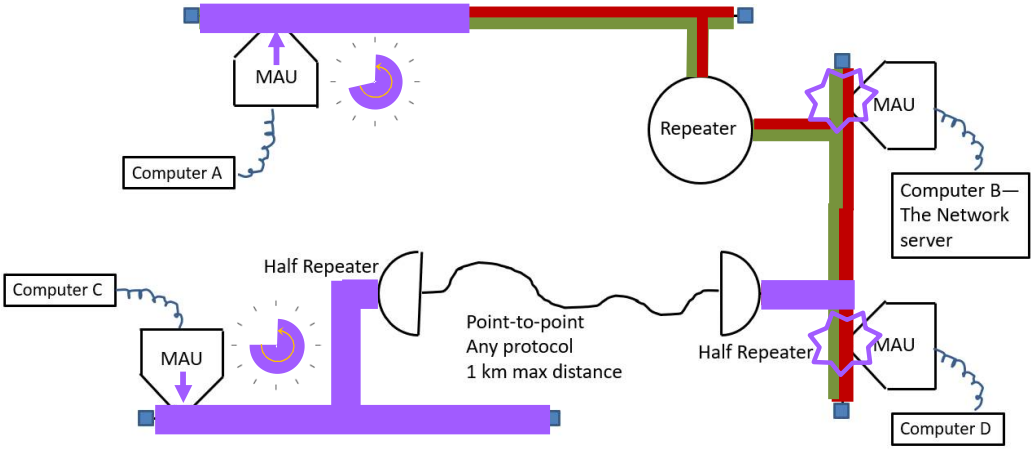
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Signals continue propagating.
Computers B and D are still oblivious and scooping up garbage.



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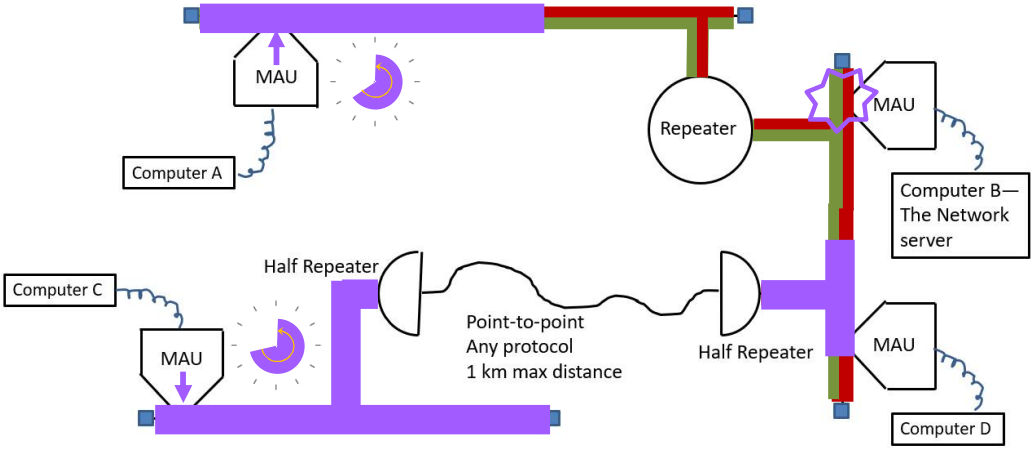
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
A collision signal has reached Computer D
Computer D abandons the frame-bits in its buffer and begins waiting for an idle network.



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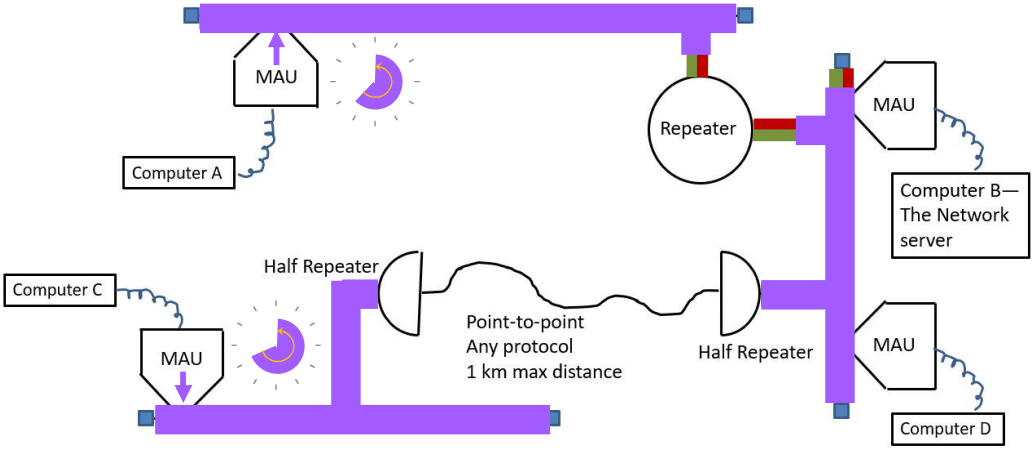
A collision signal has reached Computer B
Computer B abandons the frame-bits in its buffer and begins waiting for an idle network.



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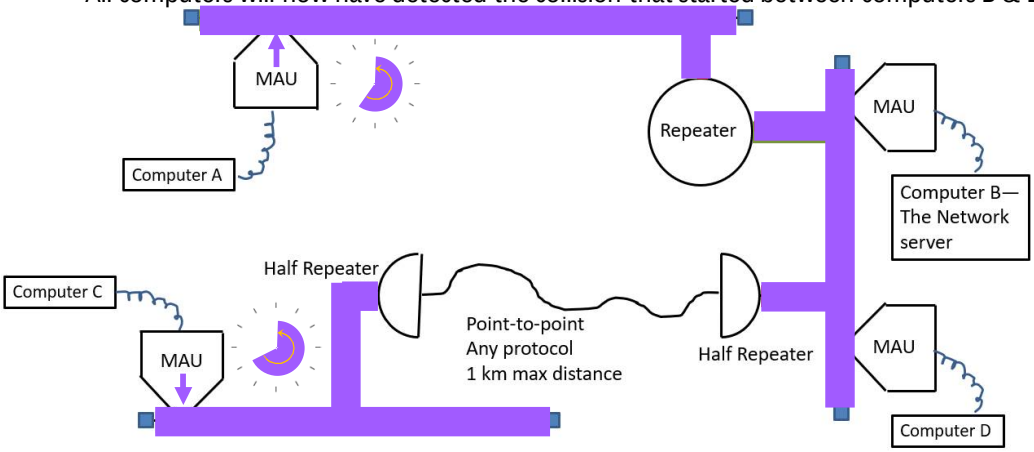
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.

Computers A and C continue sending the collision signal until enough time has passed for each of them to be assured that the entire network is flooded with their collision signals.

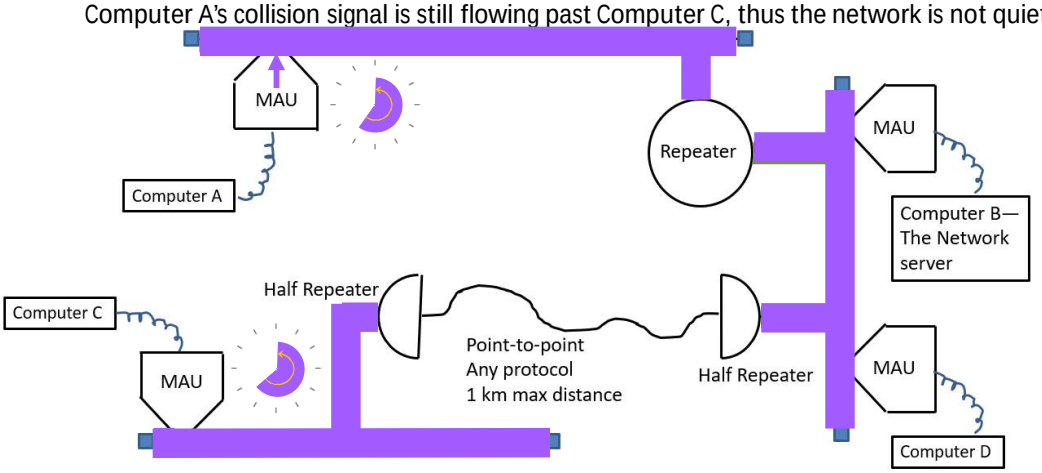
All computers will now have detected the collision that started between computers B & D.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

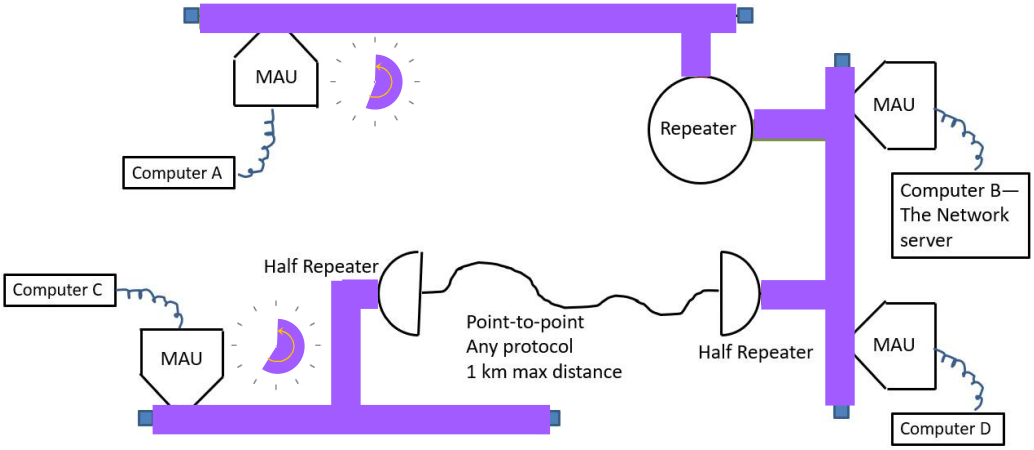
Proper frame length: All collisions detected by all devices on the network.
Computer C has sent its collision signal long enough.
It stops sending and remains quiet for its randomly computed back-off interval.
Computer A's collision signal is still flowing past Computer C, thus the network is not quiet at C.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

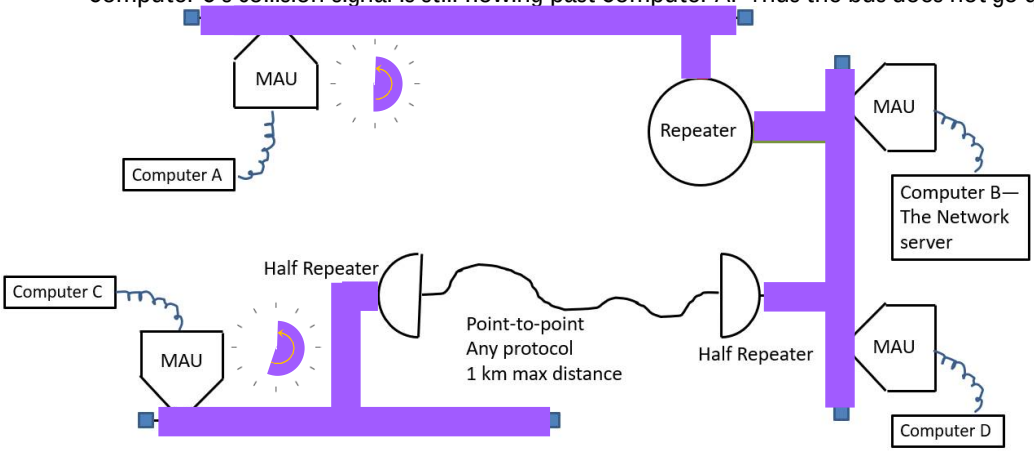
Proper frame length: All collisions detected by all devices on the network.
Signals keep propagating.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

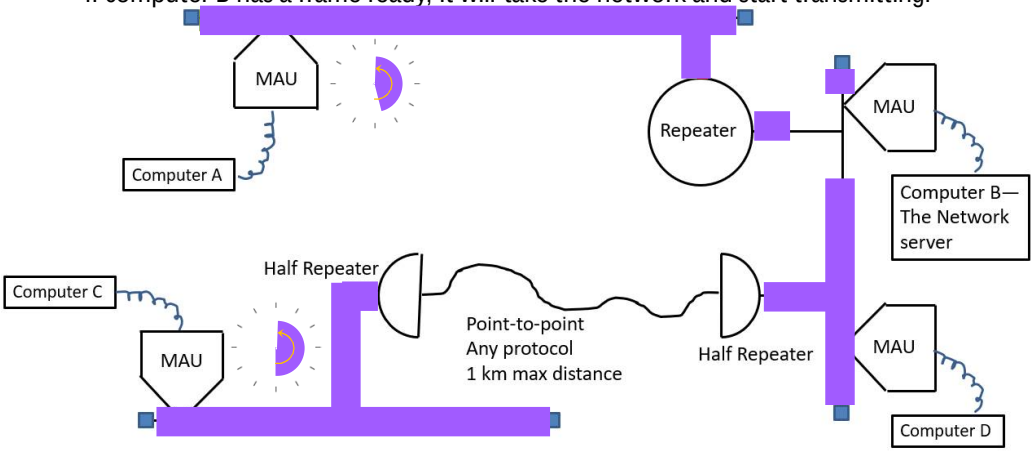
Proper frame length: All collisions detected by all devices on the network.
Signals keep propagating.
Computer A has been sending a collision signal long enough. It stops sending.
Computer C's collision signal is still flowing past Computer A. Thus the bus does not go quiet a A.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
The "tails" of the collision signals flow past each other near Computer B
A quiet network starts radiating from this point.
If computer B has a frame ready, it will take the network and start transmitting.



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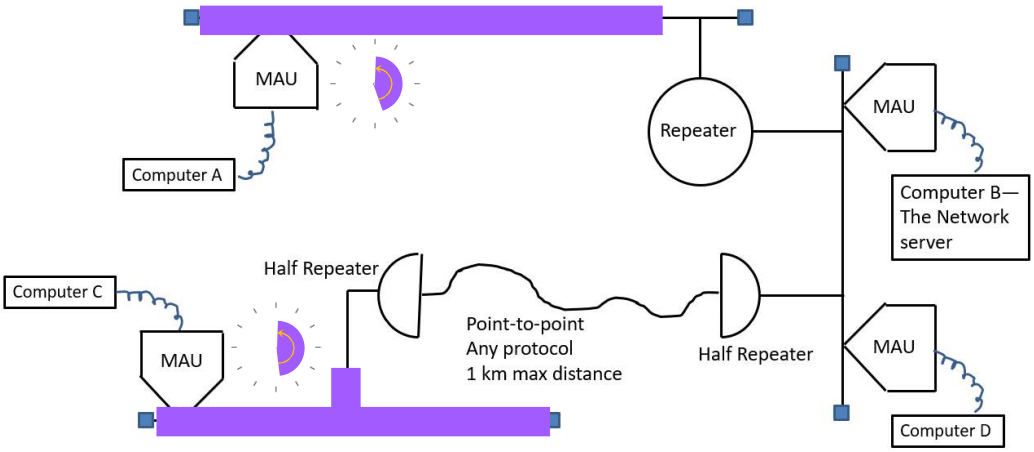
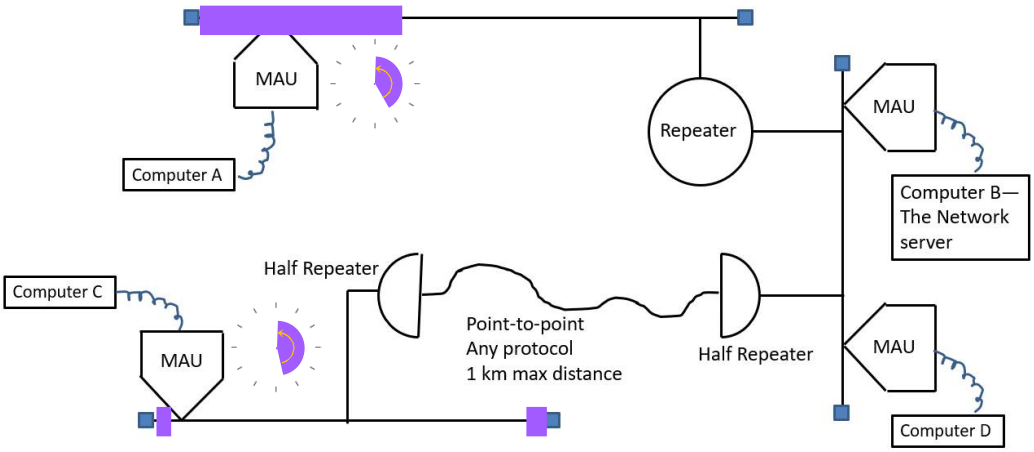
Proper frame length: All collisions detected by all devices on the network.
Signals keep propagating.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

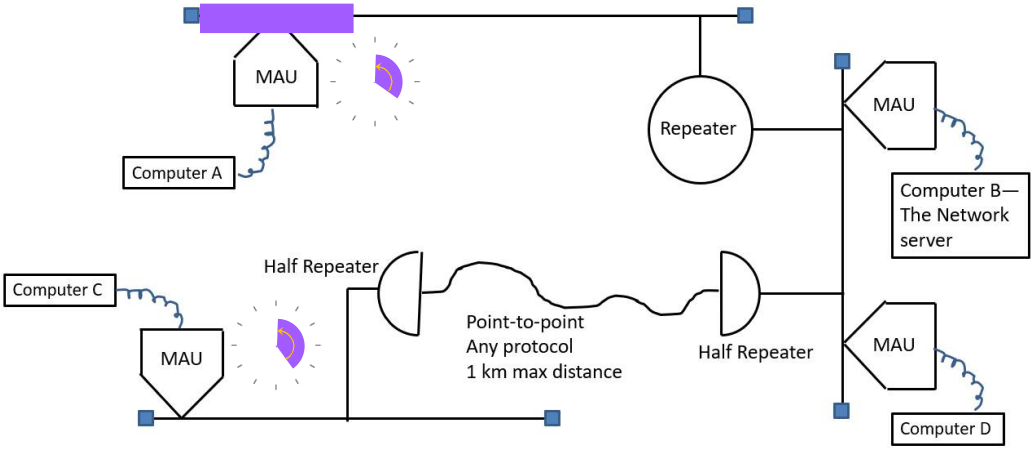
Proper frame length: All collisions detected by all devices on the network.
Computer C now sees an idle network but is not allowed to transmit until its timer runs out.
Signals keep propagating.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

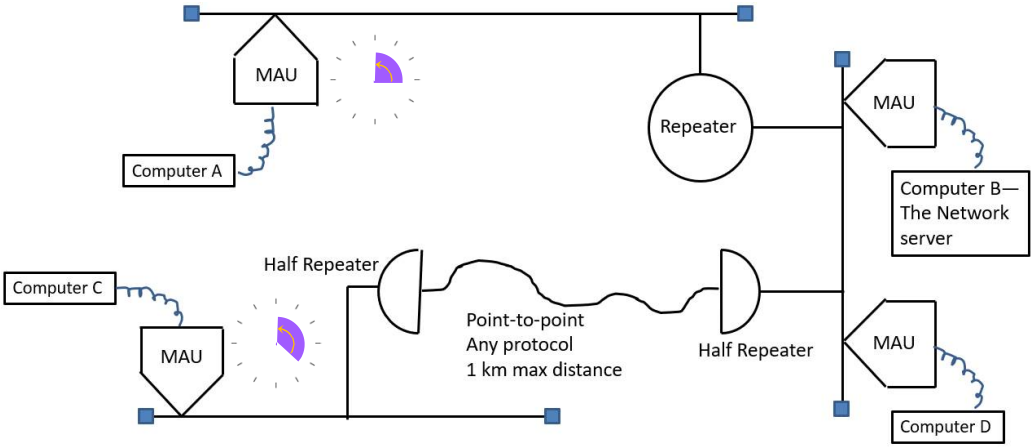
Proper frame length: All collisions detected by all devices on the network.
Computer C now sees an idle network and if ready, could start sending. Apparently it was not ready.
Signals keep propagating.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

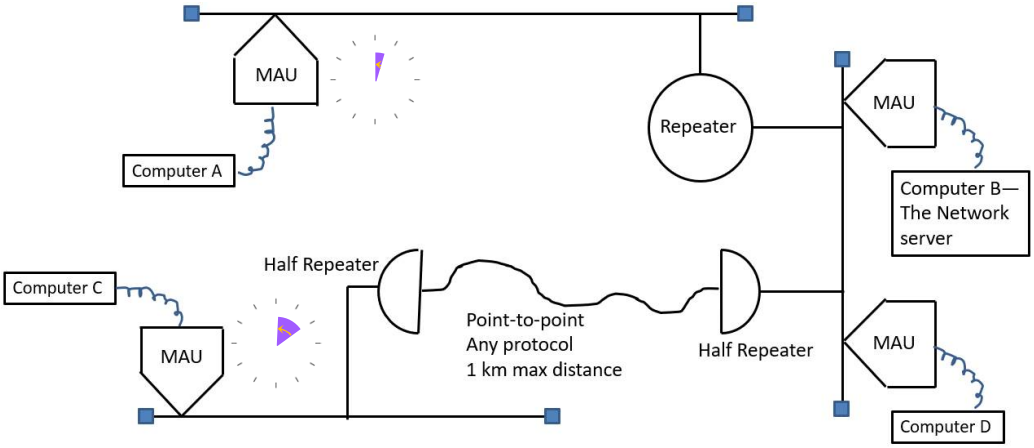
Proper frame length: All collisions detected by all devices on the network.
Computers A and C have timers running, must wait for timer to run out.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Timers continue running down.
During this interval any other computer could take the network.



Some things about Wednesday's class:

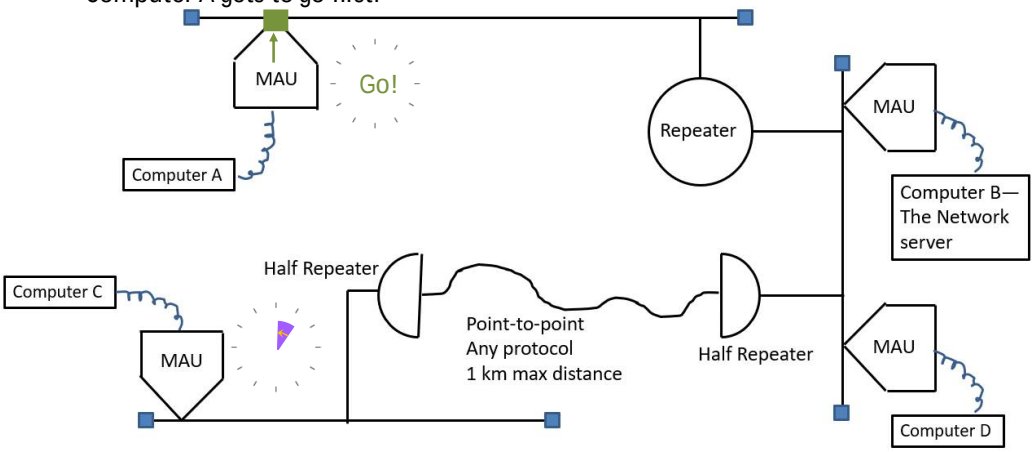
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.

Computer A's timer runs down first—it is now free to transmit.

Carrier sense: The bus is quiet. Computer A of course has a frame to transmit. (So does C.)

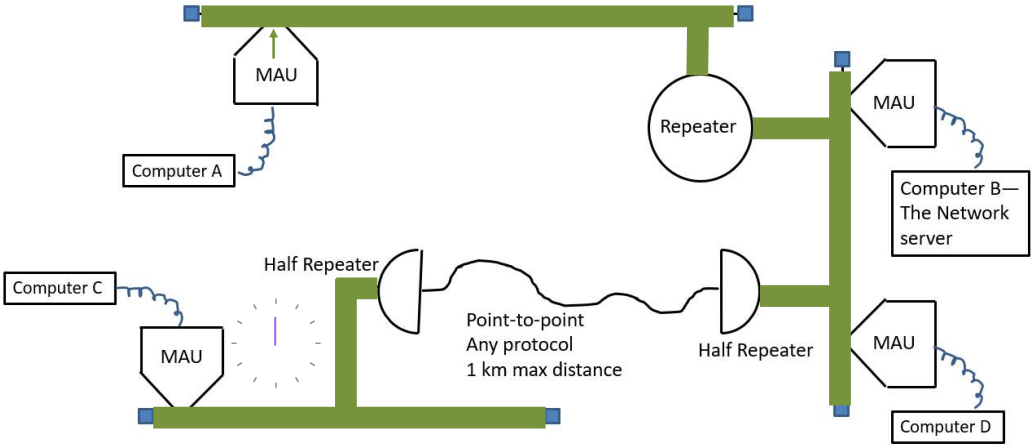
Computer A gets to go first.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

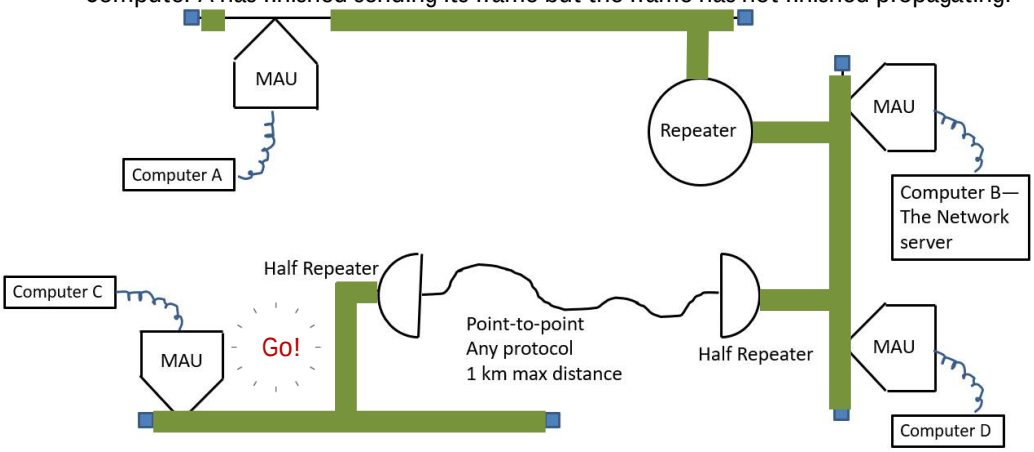
Proper frame length: All collisions detected by all devices on the network.
By design of the computed time intervals, Computer A's frame will flood the network before computer C's timer runs down.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Computer C's timer has run down
Computer C still senses carrier from A's frame—it must continue waiting.
Computer A has finished sending its frame but the frame has not finished propagating.



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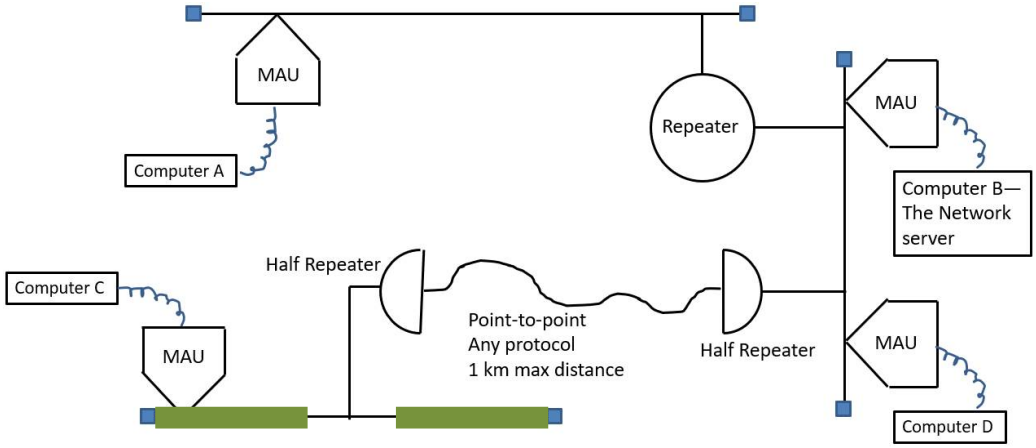
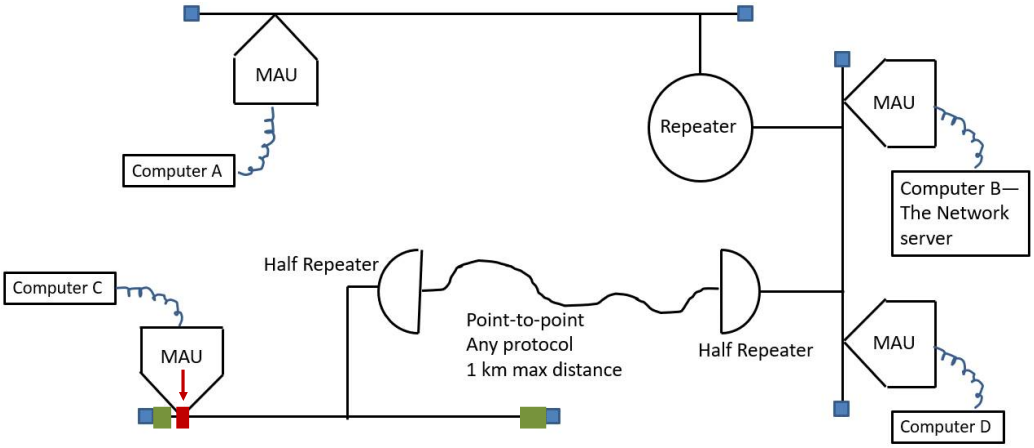
Proper frame length: All collisions detected by all devices on the network.
Computer C still senses carrier from A's frame—it must continue waiting.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Computer C still senses a quiet bus, it has a frame ready, it starts transmitting.



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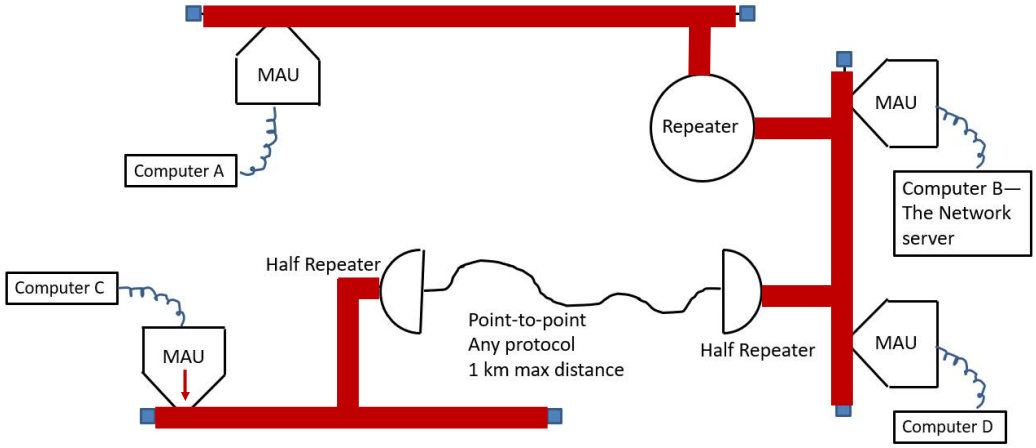
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

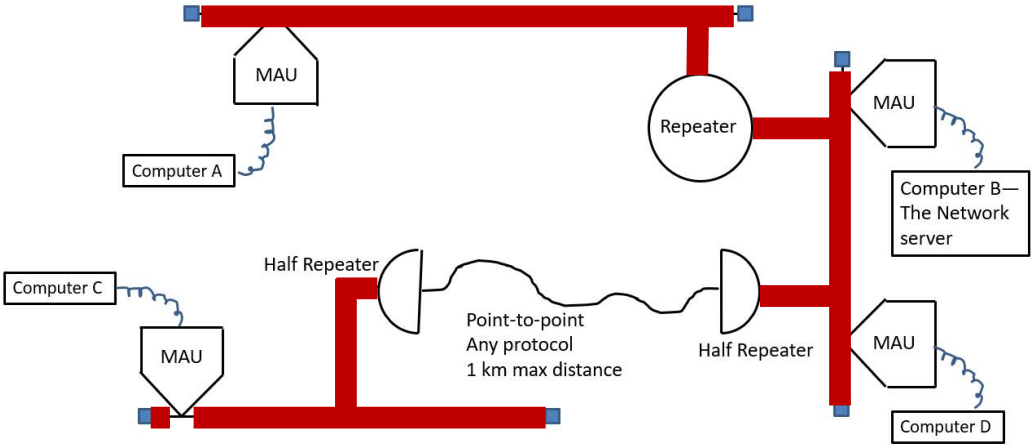
Proper frame length: All collisions detected by all devices on the network.
Computer C still senses a quiet bus, it has a frame ready, it starts transmitting.
This time, by chance, there is no collision. The signal propagates through the whole network.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Computer C is done sending. Signals keep propagating.
Computer D keeps slurping up the frame intended for it. (So do all the others, but they discard.)



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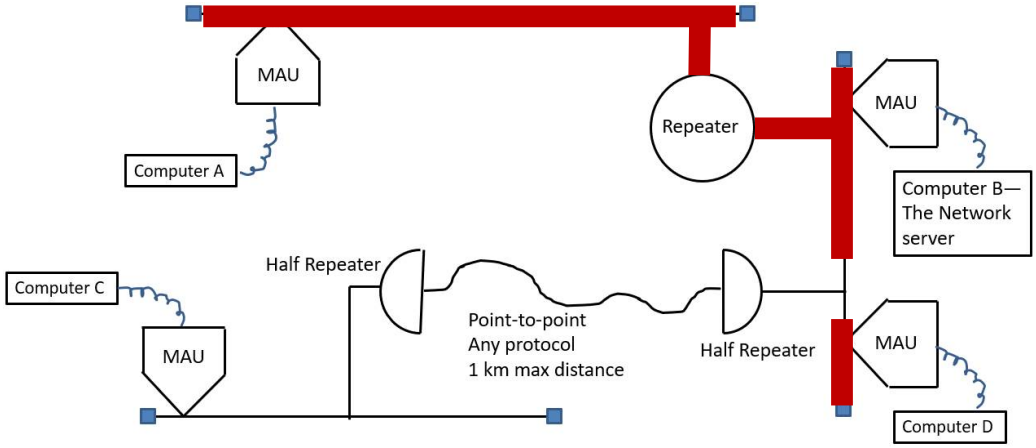
Proper frame length: All collisions detected by all devices on the network.
Signals keep propagating.



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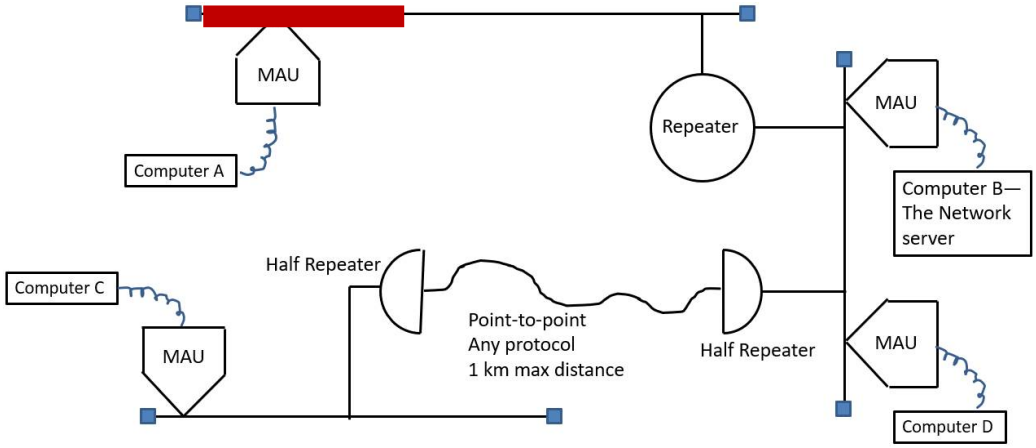
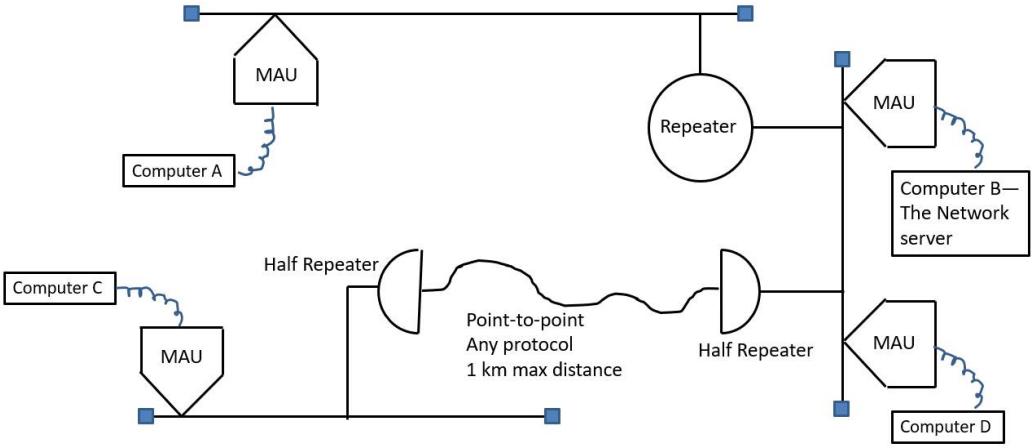
Proper frame length: All collisions detected by all devices on the network.
Signals keep propagating.

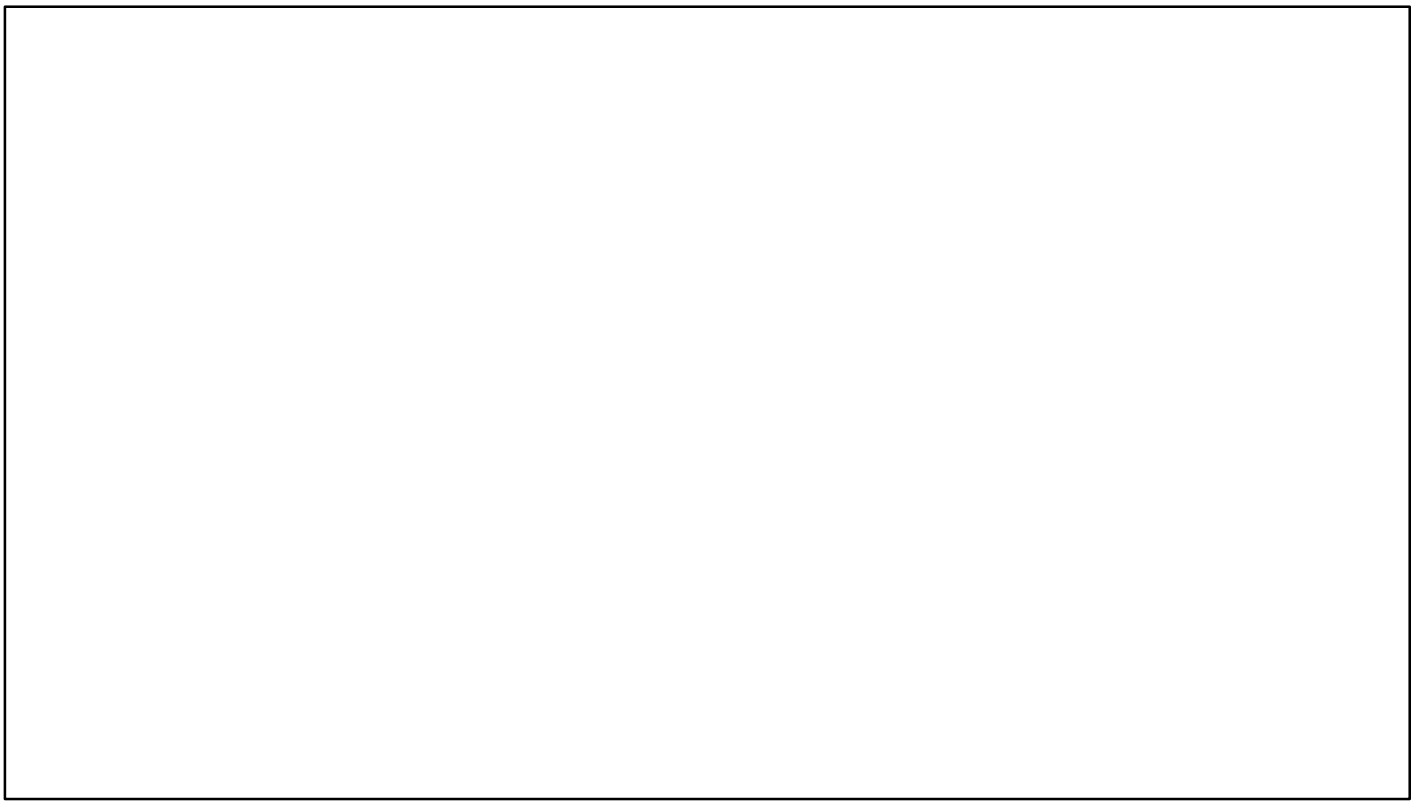


Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Proper frame length: All collisions detected by all devices on the network.
Both computer A and computer C have worked through the collision and successfully communicated.

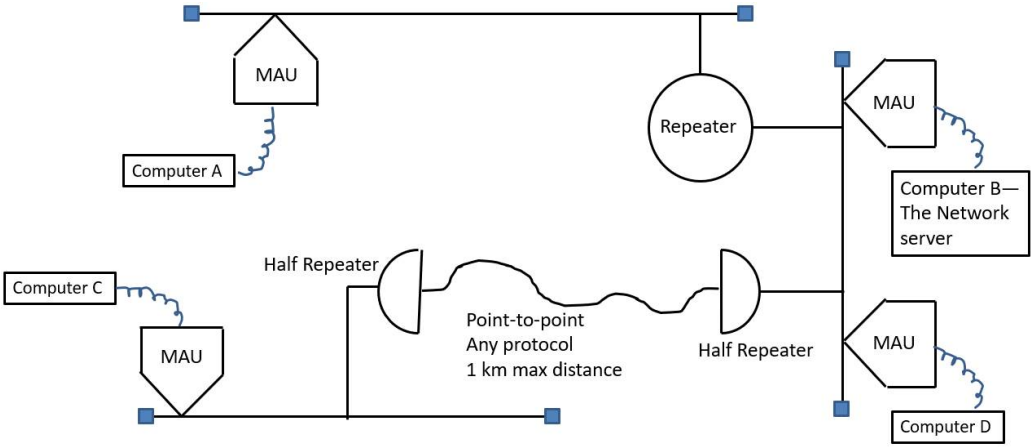




Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.



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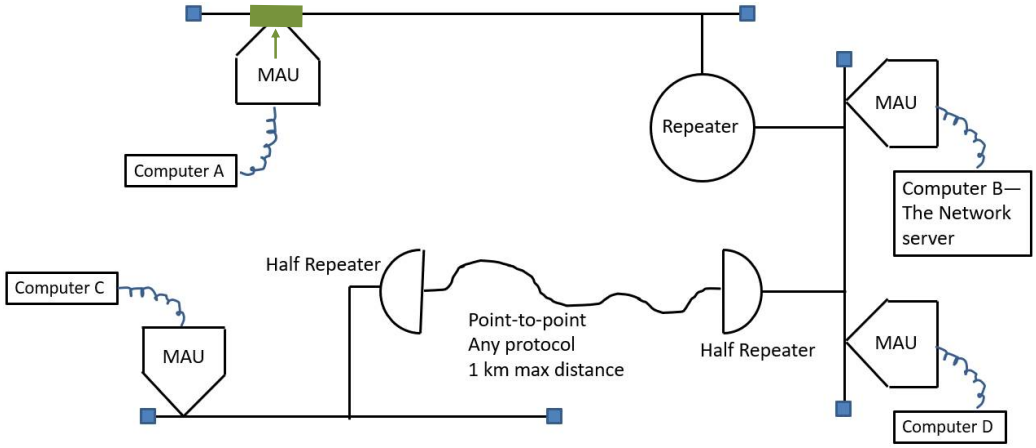
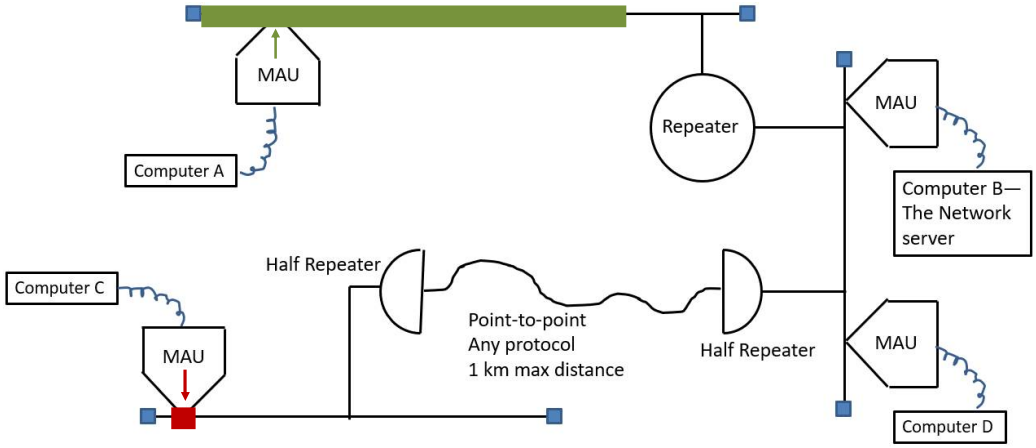
Frame length too short: Collisions will not be properly detected by all devices on the network.
Computer A finds network is silent ("CS"). Starts sending a frame to Computer B ("MA")
Continues sending—frame propagates.



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
Computer A continues sending a frame to Computer B ("MA"), the frame propagates.
Meanwhile, Computer C finds the network idle (at its location) and starts sending a frame to D



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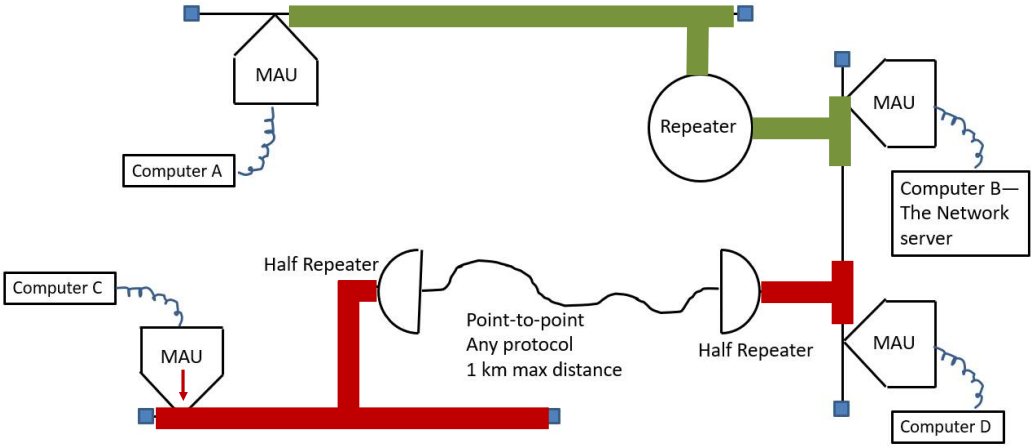
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
Computer A finishes sending its frame to Computer B ("MA"), the frames propagate.
Computer B recognizes that a frame is arriving—starts syncing clock to preamble.



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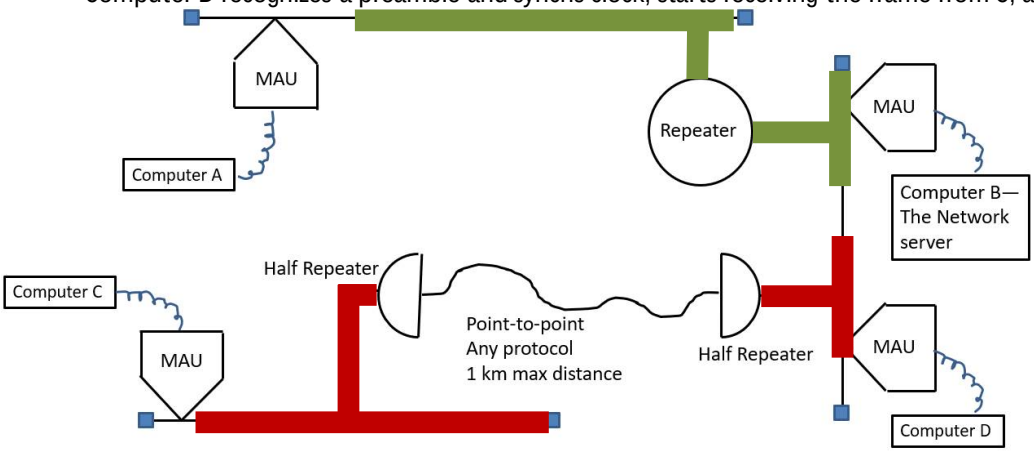
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.

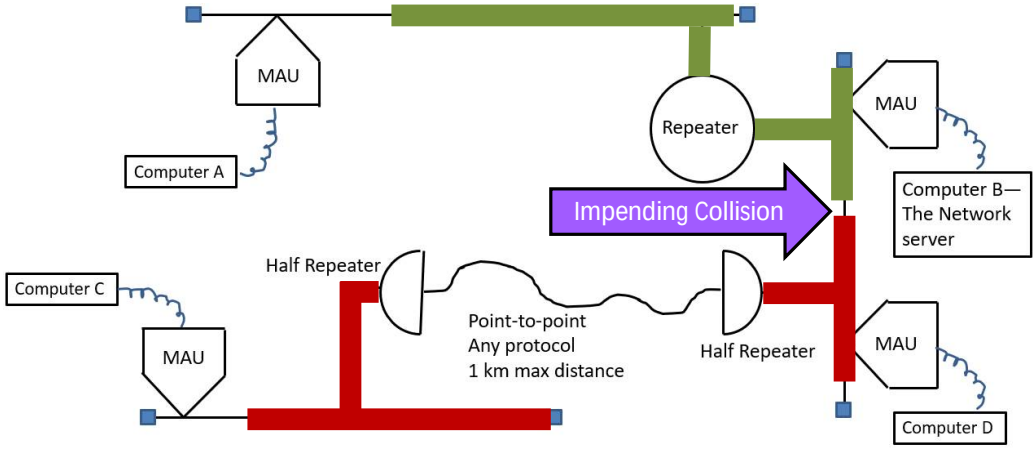
Computer C is done sending its frame to Computer D ("MA"), the frames propagate.
Computer B recognizes that a frame is arriving—starts syncing clock to preamble.
Computer D recognizes a preamble and synchs clock, starts receiving the frame from C, all is good



Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
A collision is about to happen. So far, no harm done.



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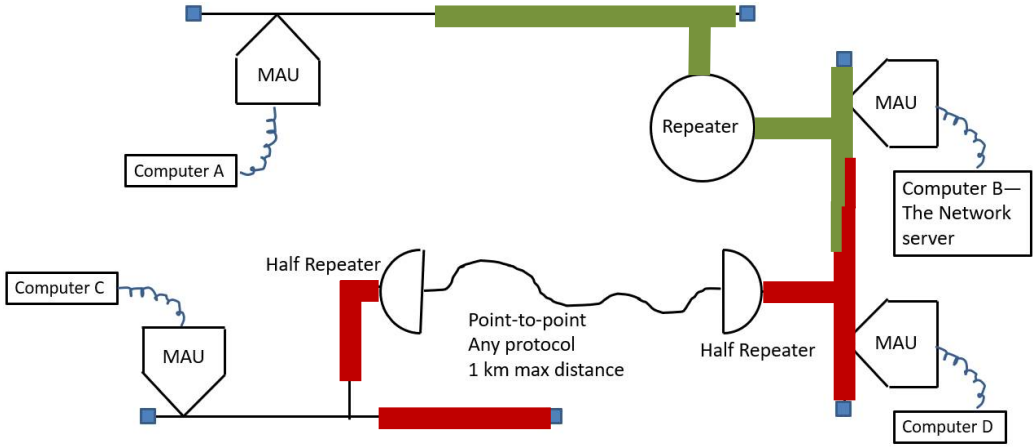
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
A collision is in progress. Voltages in the overlapped area superimpose.
Along the length of the collision there are no devices attached—collision is unnoticed, all is good.

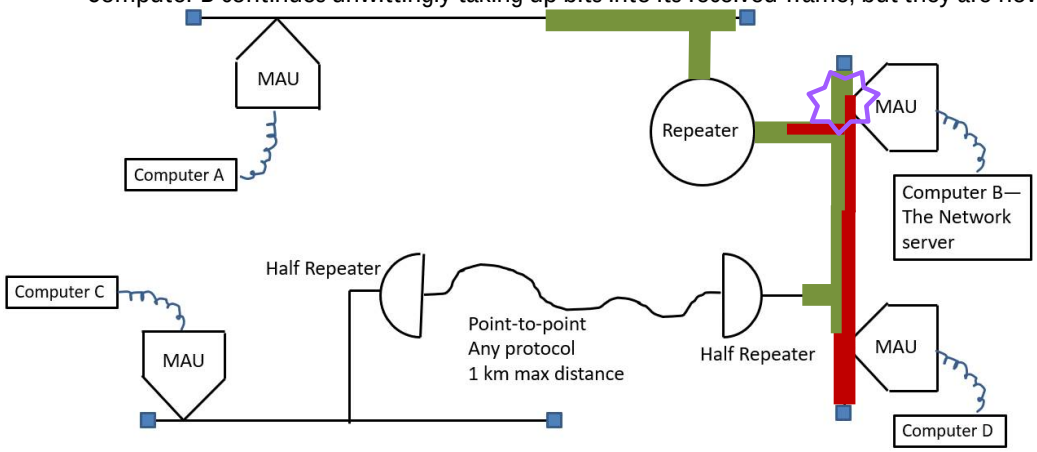


Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.

The collision has propagated to Computer B's MAU.
Computer B is not transmitting. It has no way to detect the collision.
Computer B continues unwittingly taking up bits into its received frame, but they are now garbage.



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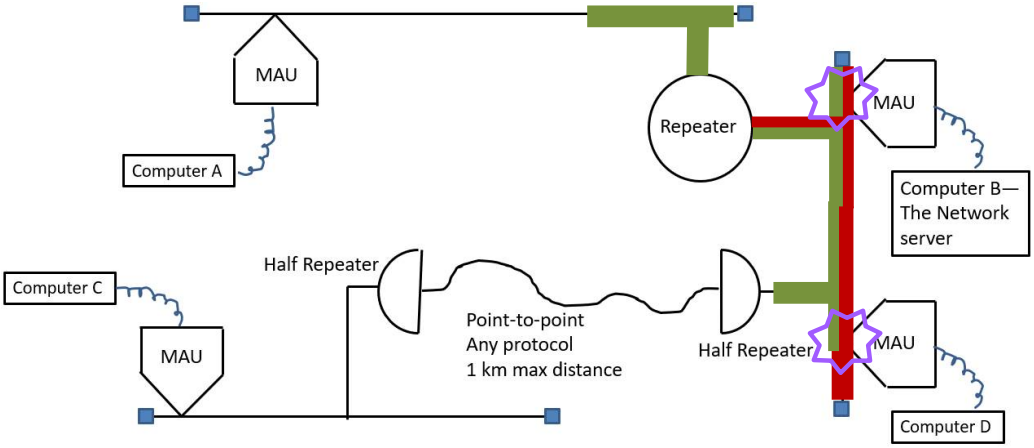
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
The collision has reached computer D, which is also not transmitting, thus taking up garbage now.



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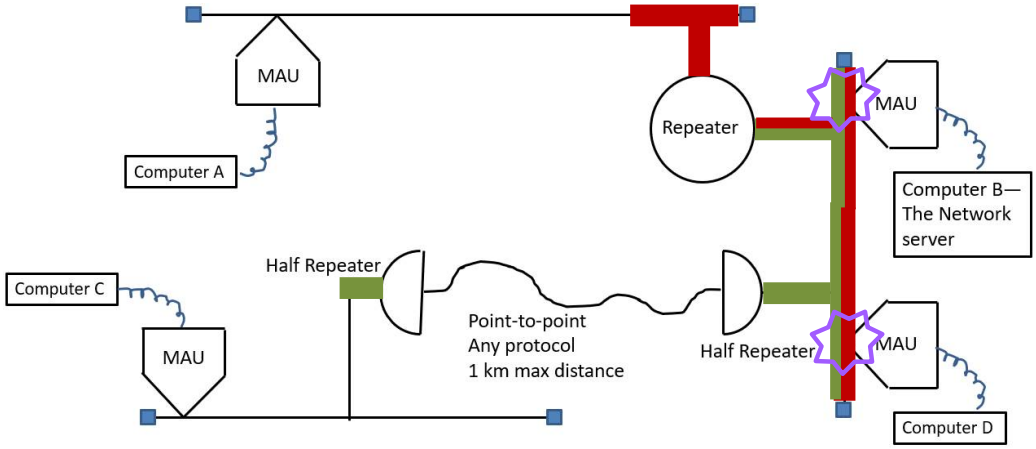
Frame length too short: Collisions will not be properly detected by all devices on the network.
The collision continues propagating.



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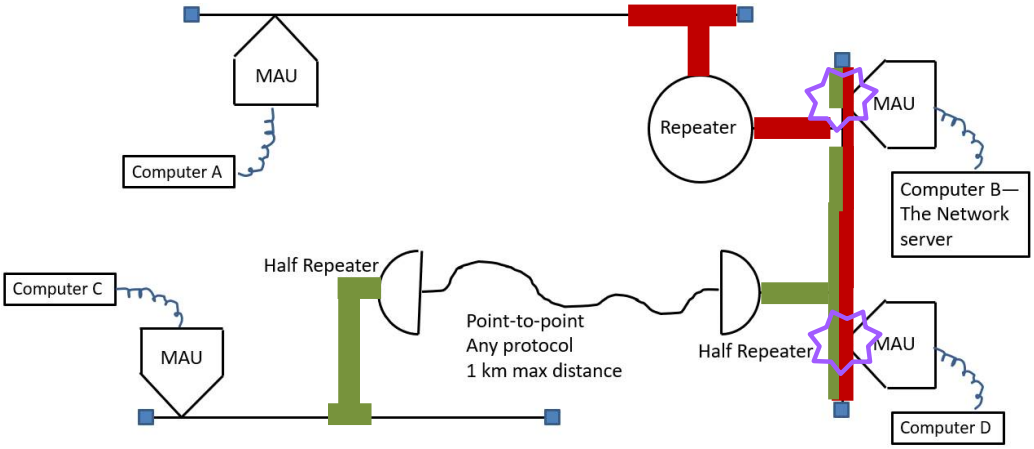
Frame length too short: Collisions will not be properly detected by all devices on the network.

The collision continues propagating.



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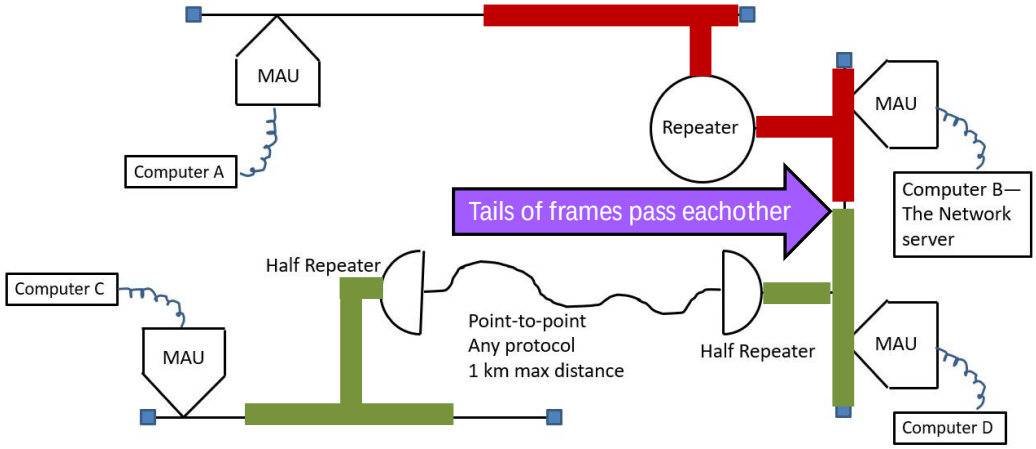
Frame length too short: Collisions will not be properly detected by all devices on the network.
No more collision!



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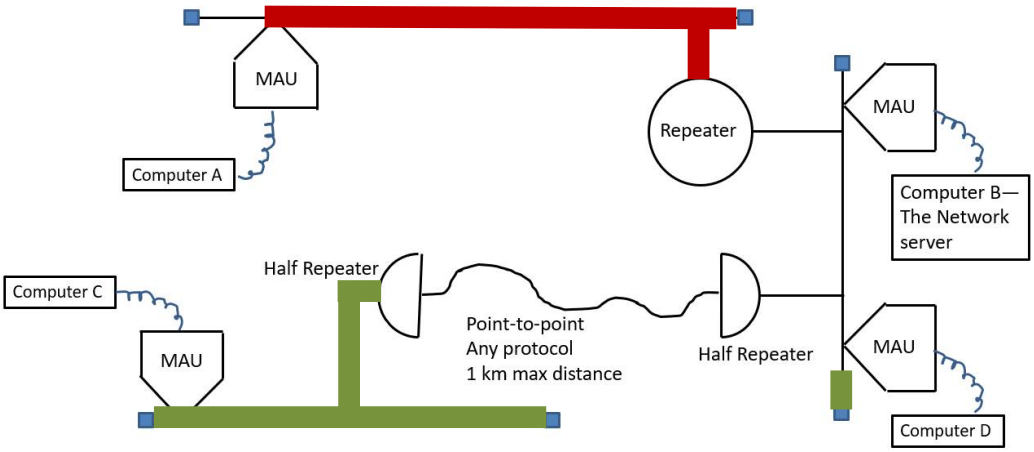
In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

Frame length too short: Collisions will not be properly detected by all devices on the network.
Computers A and C are not transmitting—have no way to detect that a collision occurred.



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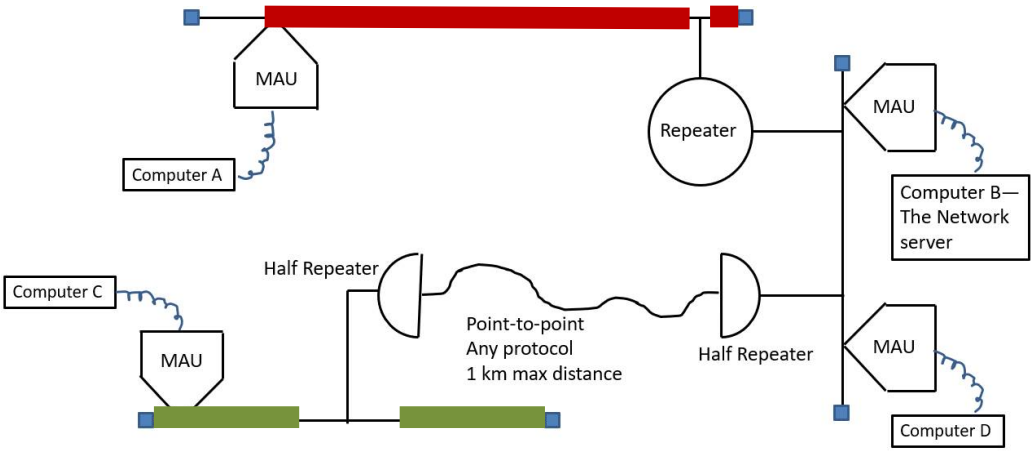

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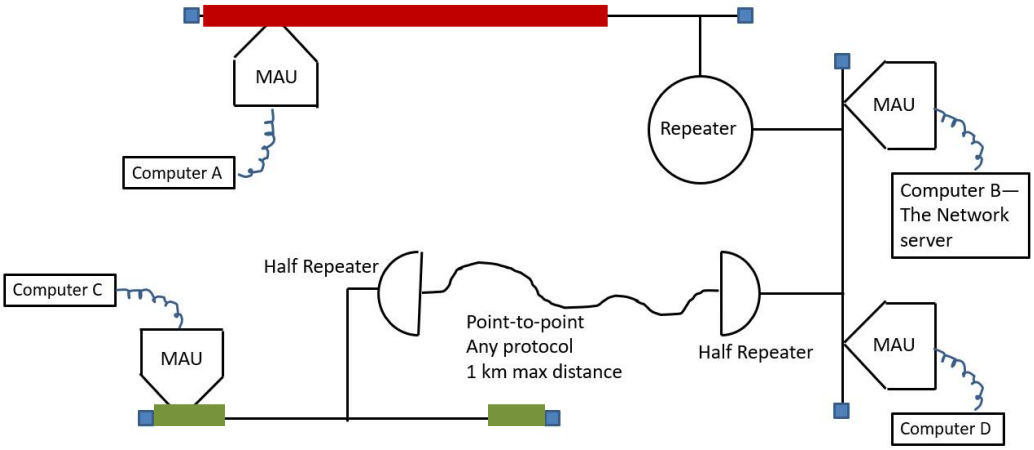

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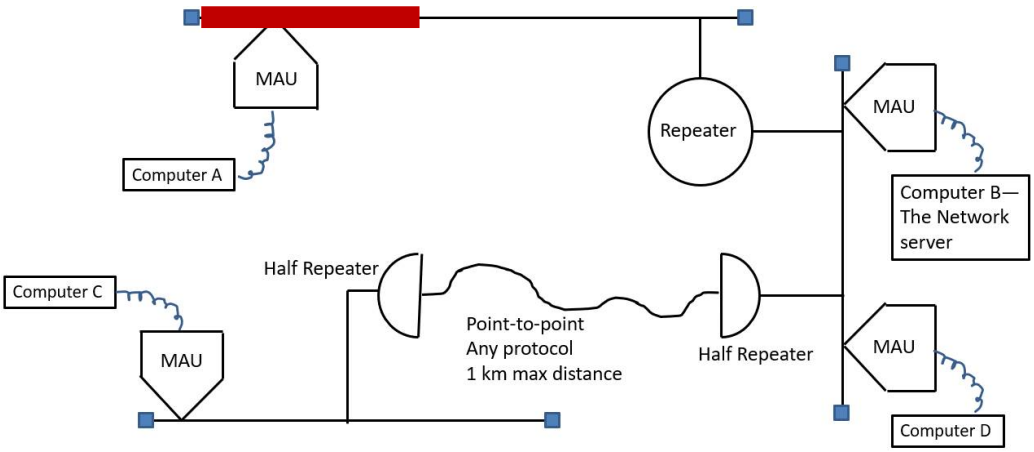

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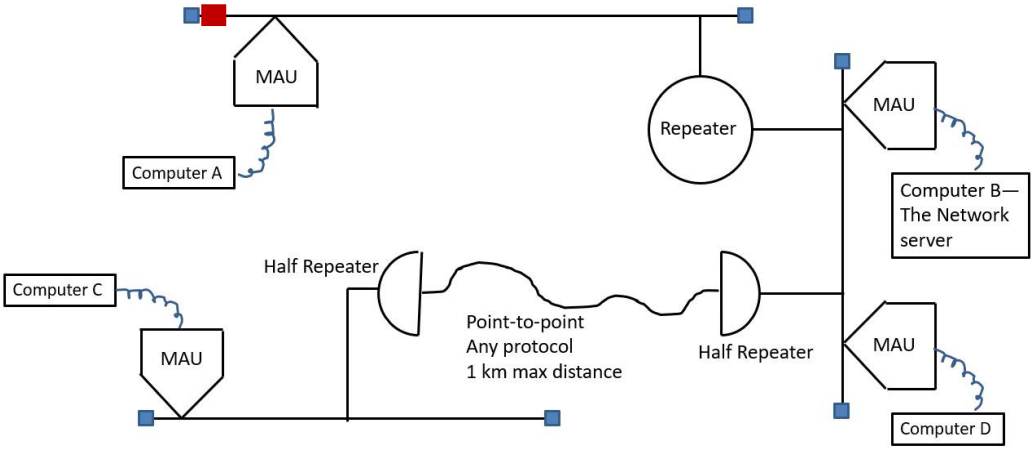
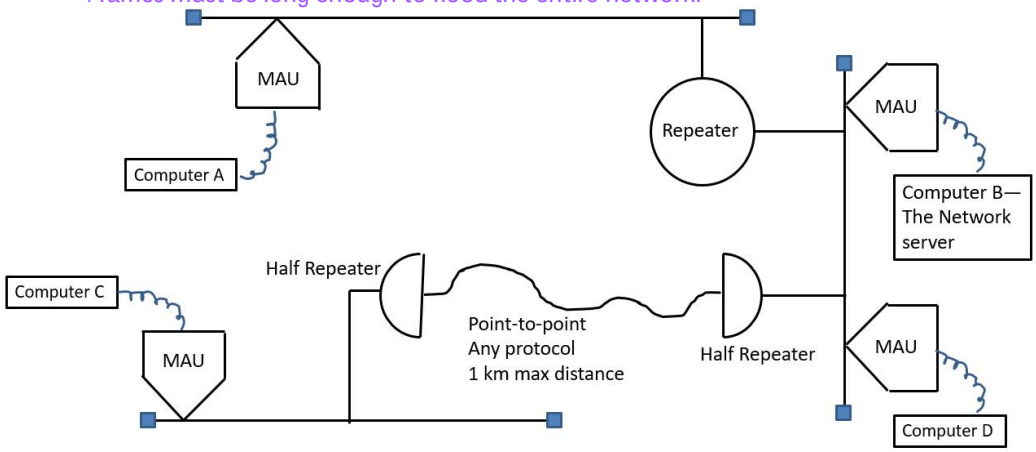
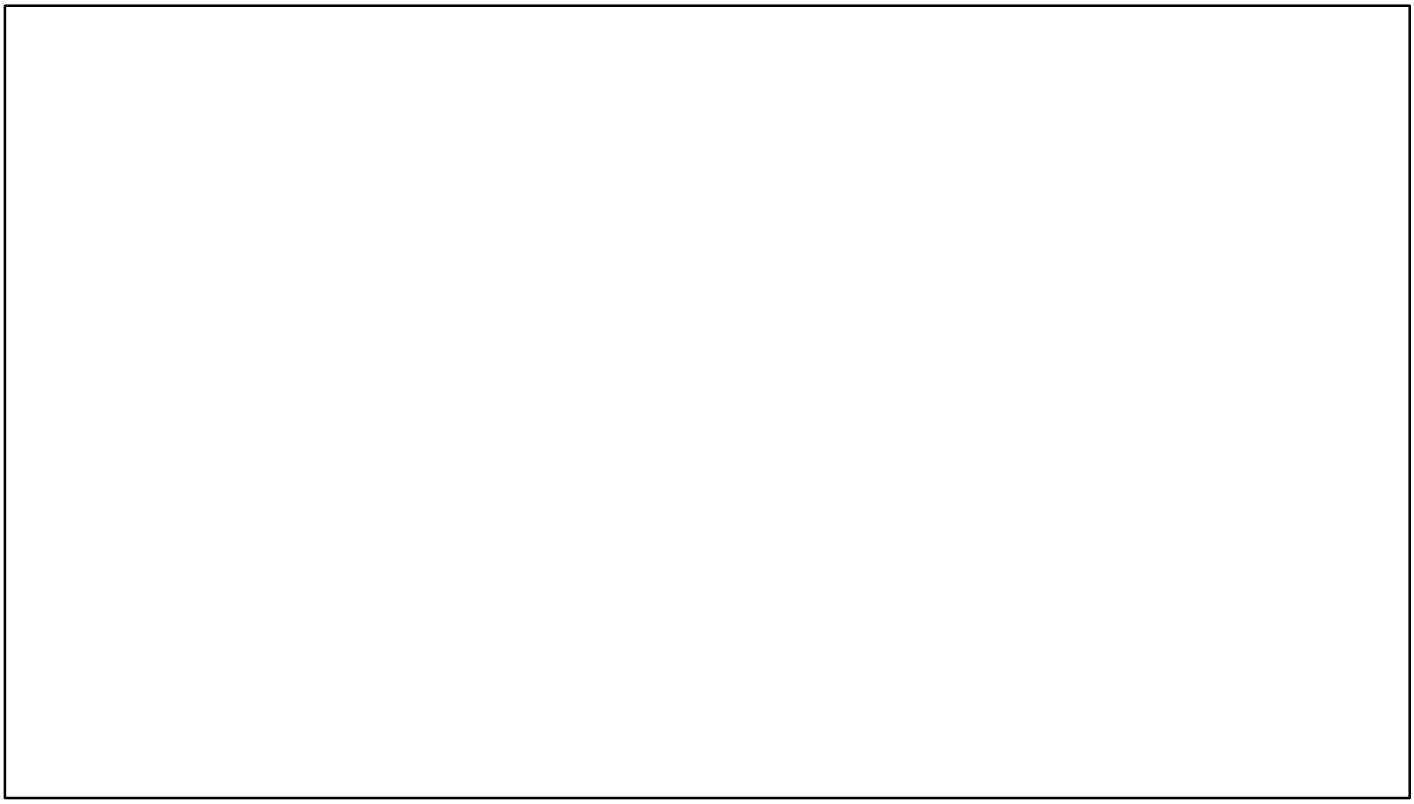


Some things about Wednesday's class:

In 10-Base 5 Ethernet ("Original Ethernet") a frame has to be long enough to flood the network, otherwise not all devices attached will properly detect every collision.

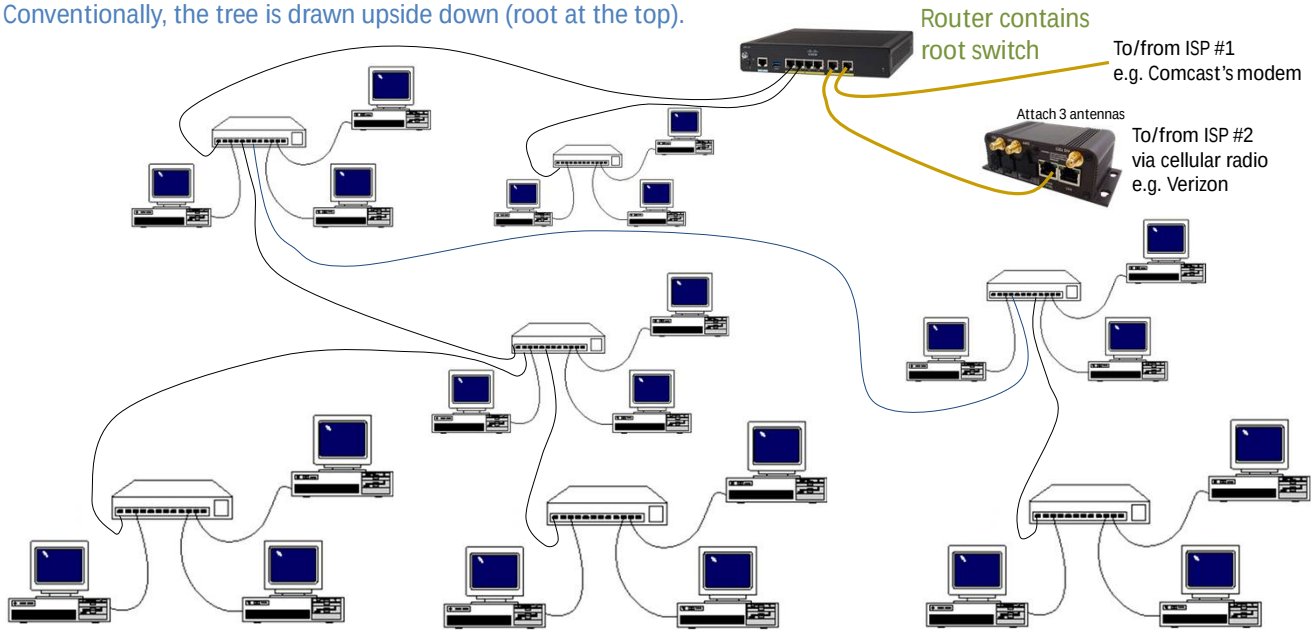
Frame length too short: Collisions will not be properly detected by all devices on the network.
Collision never detected at A or C
Computers B and D are left with garbage
Frames must be long enough to flood the entire network.





Ethernet: Hubs, switches, repeaters, bridges, routers, WAPs—what are these things?

Hubs and Switches must be arranged in a tree.
Typically any servers and any routers (to other networks, e.g. the Internet) are connected at the root of the tree.
Conventionally, the tree is drawn upside down (root at the top).



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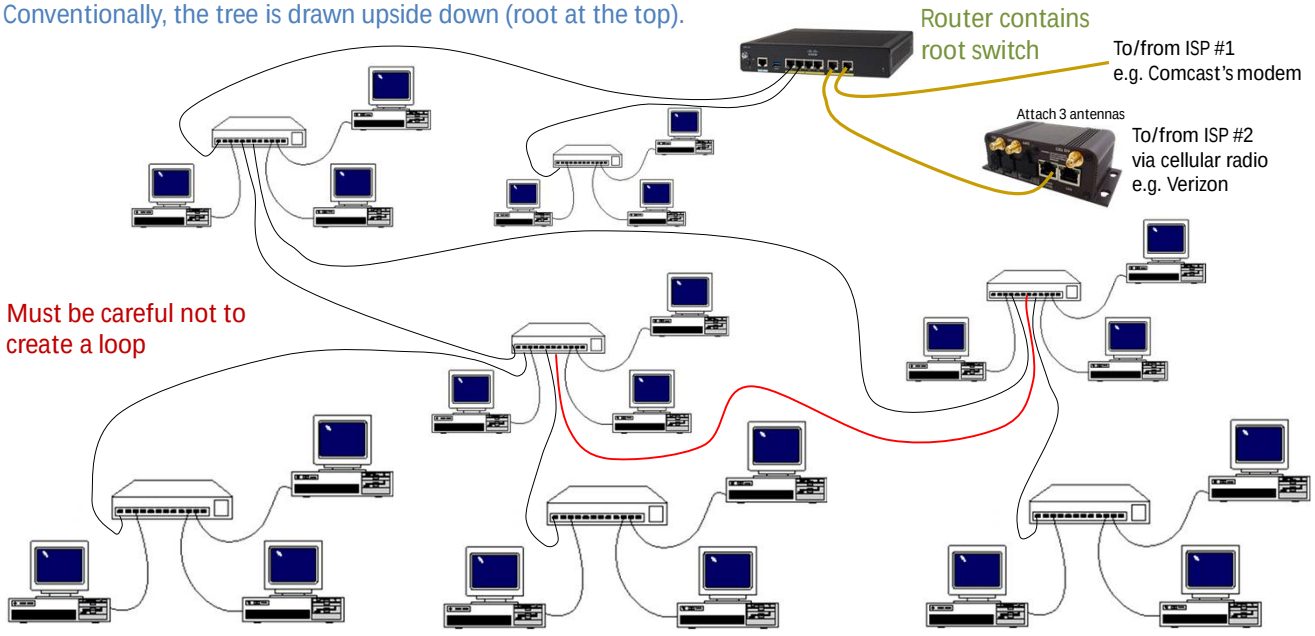

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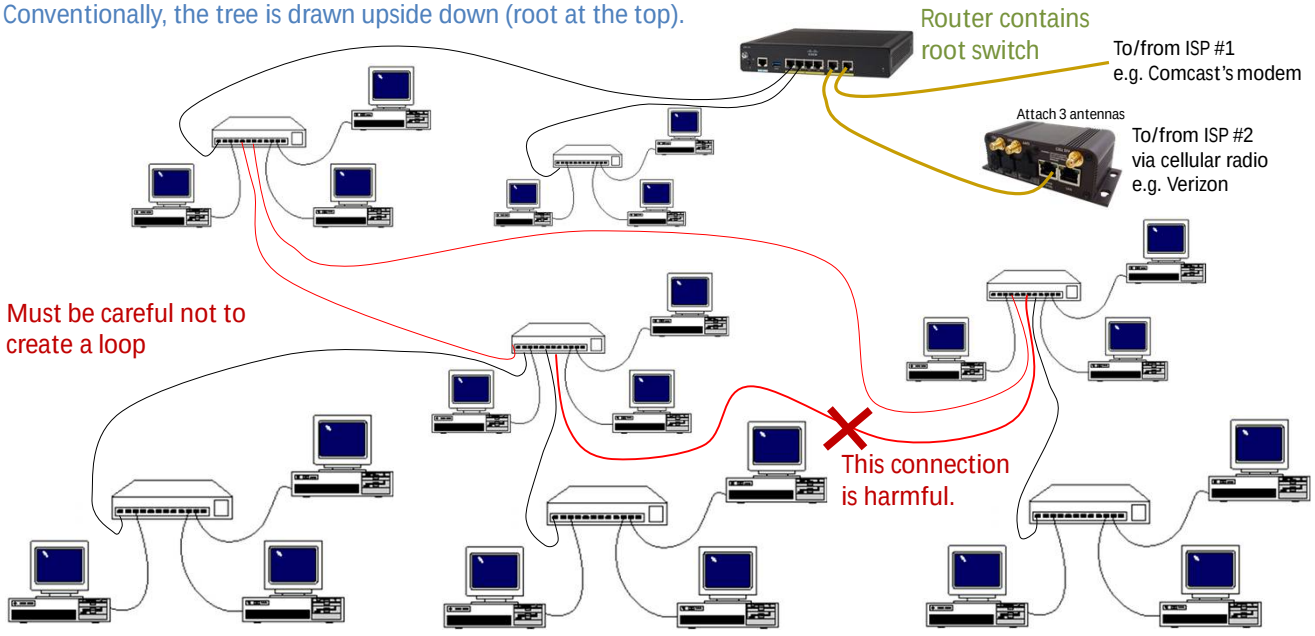

Bluetooth®

Operates on the same ISM band as Wi-Fi (2.4 Ghz)

Is essentially a point-to-point protocol, not a network. It is designed to replace a wire, say to you ear-buds.

To establish a link, two Bluetooth-capable devices must be *paired*.
The way paring is established varies depending on the Bluetooth versions in use. (Worst case, enter PIN numbers)
Normally paring lasts for a session. (As long as in radio range, as long as power is on, etc.) Then it is lost.

Most Bluetooth devices, once paired, can be *bonded*.
Bonded pairs, when not paired, automatically send out beacon signals and listen for other beacons to attempt to automatically re-establish the pairing. These days most Bluetooth devices, once paired, automatically bond.

A Bluetooth device may be paired to more than one device.
Each pairing is a point-to-point connection acting individually and unaware of the other pairing.
A smartphone could route data from one pairing to the other, but this would be a software feature of the phone.

Main advantages of Bluetooth:
Lower power consumption on an assumption of nearby devices. (Less than 30 feet or so.)
Low transmission latency is possible—communication is direct between two devices, no switches, routers, etc.
No SSID, passwords, etc. for simple consumer-oriented application.

Yet another wireless protocol in the same ISM bands as Wi-Fi.

Very similar to Bluetooth at the radio level, except lower speeds.
Low power—battery conserving.
Zigbee devices must operate for at least two years on primary batteries. (A coin cell is a primary battery.)
Intended for short distances that are similar to Bluetooth.
Uses protocols similar to Ethernet and Wi-Fi including CSMA/CA

Mesh network—this is very different from Bluetooth and from Wi-Fi
Each Zigbee device periodically looks for more Zigbee devices that identify as belonging to the network.
They promiscuously connect together and probing the resulting mesh network to discover possible routings.
Any loops found are automatically noted and avoided.
The ZigBee devices may be moved around geographically—the network routing will adapt after a few minutes.
(Wi-Fi is bound to WAPs that must be strategically placed geographically.)

What is Bandwidth?

In the context of *computing*, bandwidth is usually measured in *bits per second*.

Higher bandwidth simply means that a given amount of data transfers in less time.

But in *communications theory*, bandwidth is measured in hertz. (Hz)
1 Hz = <one something>per second. (Where <something> is supposed to be obvious and is considered dimensionless.)
Example: A 1 Hz sine wave makes one *cycle* per second.

It can be proven that any practical signal that could be manufactured in the lab can be synthesized as a sum of sine waves.

https://www.desmos.com/calculator/lab9nylxsi
In the sawtooth shown, the fundamental frequency is $1/(2\pi)$ Hz. (About 1/6.2 Hz)
But notice that in order to get a good-looking sawtooth drawn, one needs to add in higher freqs. (up to $4/(2\pi)$ Hz shown)
Thus a typical signal requires considerably more bandwidth than its fundamental frequency.

Binary digital signals tend to be square waves—which need lots of higher-frequency sinusoids to construct them.
Thus modern digital systems do not use just plain square waves and have a decidedly analog nature when they are on the Ethernet wire or in the air as Wi-Fi signals. We have already seen the oscilloscope trace of 10 Mbps Ethernet—not square!

So computing bandwidth—speed—requires high frequencies.
Sophisticated modulation that uses non-square signals improves the bit rate available from a given frequency range.
All of this is a major topic in EGR 363, Communication Systems.
There are sophisticated methods of analyzing this in the so-called frequency domain. It is a big topic.

OK, back to where we left off on Wednesday. . .