Jason Anderson
852 HW1 - Summary of Metcalfe Ethernet paper

The paper proposes five mechanisms for reducing the probability and cost of losing a packet, based on lessons learned from the Aloha packet radio network and others. These are important on a shared-bus network with distributed control, where transceivers must cooperate to maintain efficiency.

1. **Carrier Detection** — a transmission from a carrier is phase encoded (I presume using Manchester coding) so that bits are encoded using transitions in the DC voltage from low to high or high to low, representing a 1 or 0 respectively (according to IEEE 802.3, the reverse for G.E. Thomas encoding). Transceivers, therefore, can "listen" on the wire for a transition in two clock cycles, which would indicate that another carrier is currently transmitting. The transceiver can then delay sending until the transmission ceases. This method allows for increased efficiency with longer packets compared to non-carrier sensing methods, and also limits collisions to the beginning of transmissions, where two or more carriers were waiting for a transmission to finish.
2. **Interference Detection** — transceivers will also listen at the same time as transmitting, and compare the received bits to those that are being transmitted. Any discrepancy indicates that another station is attempting to transmit at the same time, and that any receiver would be confused by the colliding packets. The transceiver will stop transmission and wait a random interval before retrying, while presumably the colliding transceiver will do the same. This method allows detection of colliding packets early in the transmission, without much waste.
3. **Packet Error Detection** — the final four bytes of a transmitted packet is a computed checksum of the preceding bytes, which is recalculated by the receiver and compared to the transmitted value. A discrepancy indicated a damaged packet, which is dropped. This method has an added advantage beyond the scope of the paper: in today's Internet, where a packet may traverse dozens of Ethernet transceivers, a packet is dropped immediately after an error occurs, which saves capacity by not transmitting packets that will simply be dropped by endpoints.
4. **Truncated Packet Filtering** — transmissions that are cut short by carrier sensing and interference detection are typically only a few bits long. These packets are dropped by the receiving hardware, saving processing load on the listening station software.
5. **Collision Consensus Enforcement** — when transceivers experience interference, they will transmit a signal ("jam the Ether") that causes the other transmitting stations to experience interference and retry their transmissions. This ensures that all stations are aware of the interference and don't mistakenly send damaged packets.

Modern CSMA/CD — Modern wired Ethernets, to my knowledge, do not rely on CSMA/CD anymore. Ethernet typically does not use a shared Ether, and consists of end to end connections with packet switches receiving and sending packets along a forwarding graph. However, CSMA/CD is still widely used in wireless networking.

MAC Issues and Gigabit Ethernet — The Media Access Control (MAC) protocol is an implementation of CSMA/CD. As noted in the Metcalfe paper, efficiency of the network decreases with shorter packets. Ethernet frames are minimally 64 bytes in length, which quickly drops to ~87% efficiency with >10 carriers.

Section 6.3 of the Metcalfe paper provides a formula for calculating the efficiency of the network, given as:

E = (P/C) / ((P/C) + (W*T))

where P = the number of bits in the packet, C = the capacity in bits per second, W = the mean number of transmission slots that must be waited in an episode of contention, and T = the time in seconds of a slot (the time required to detect a collision). The value of W*T is controlled by the propagation delay of signals across the medium, and is therefore relatively unchanging given a constant W. However, the value of P/C becomes smaller as the capacity of the Ether increases.

Assuming the values for T given by Metcalfe (16 microseconds) holds true for gigabit Ethernet, the efficiency E drops rapidly, as seen in Table 1. I included packet sizes for the minimum and maximum IEEE 802.3 packets (72 and 1526 octets). Unfortunately, I was unable to replicate Metcalfe's value of W for Q=2, but it is obvious that for gigabit Ethernet, the efficiency becomes so low as to be unusable.

Since CSMA/CD becomes unusable with high capacity Ethers, flow control is implemented with full-duplex end-to-end connections, so that no collisions are possible.

Efficiency of Ethernet with packet sizes P and number of carriers Q

Q \ P	12208	4096	1024	576	512	48		A	W
1	1.000	1.000	1.000	1.000	1.000	1.000		1	0
2	0.421	0.196	0.058	0.033	0.030	0.003		0.5	1
3	0.421	0.196	0.058	0.033	0.030	0.003		0.444444	1
4	0.368	0.163	0.047	0.027	0.024	0.002		0.421875	1.25
5	0.347	0.151	0.043	0.024	0.022	0.002		0.4096	1.370370
10	0.335	0.145	0.041	0.023	0.021	0.002		0.387420	1.441406
32	0.315	0.134	0.037	0.021	0.019	0.002		0.373734	1.581174
64	0.303	0.127	0.035	0.020	0.018	0.002		0.370779	1.675696
128	0.300	0.126	0.035	0.020	0.018	0.002		0.369323	1.697017
256	0.299	0.125	0.035	0.020	0.018	0.002		0.368599	1.707656
capacity C (Mb)	1000								
slot time T (us)	16								
	10485760								
	0.000016								