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ETHER!

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MEMO

MAY 22, 1973

TO: ALTO ALOHA DISTRIBUTION

FROM: BOB METCALFE

SUBJECT: ETHER ACQUISITION

HERE IS MORE ROUGH STUFF ON THE ALTO ALOHA NETWORK.

I PROPOSE WE STOP CALLING THIS THING "THE ALTO ALOHA NETWORK". FIRST, BECAUSE IT SHOULD SUPPORT ANY NUMBER OF DIFFERENT KINDS OF STATION -- SAY, NOVA, PDP-11, ... SECOND, BECAUSE THE ORGANIZATION IS BEGINNING TO LOOK VERY MUCH MORE BEAUTIFUL THAN THE ALOHA RADIO NETWORK -- TO USE CHARLES'S "BEAUTIFUL".

MAYBE: "THE ETHER NETWORK". SUGGESTIONS?

LAZY SUZAN
BULLETIN BOARD
PARLEY
PARLIAMENTARY PROCEDURE

I HOPE TO BE SIMULATING SOON. HELP? INPUTS?

I HOPE YOU WILL NOT BE OFFENDED BY MY ATTEMPTS TO MAKE THIS THINKING AND DESIGN APPEAR THEORETICAL.

Bob

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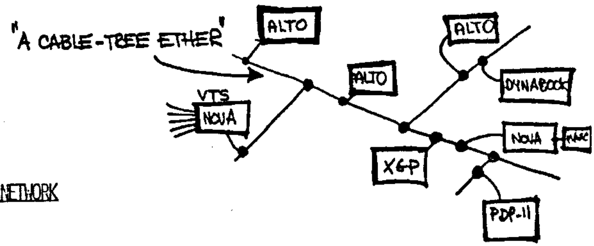
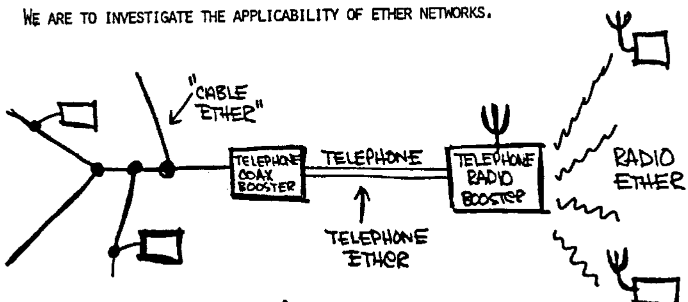


THE ETHER NETWORK

We plan to build a so-called broadcast computer communication network, not unlike the ALOHA System's radio network, but specifically for in-building minicomputer communication. We think in terms of NOVA's and ALTO's joined by coaxial cables.

While we may end up using coaxial cable trees to carry our broadcast transmissions, it seems wise to talk in terms of an ether, rather than 'the cable', for as long as possible. This will keep things general and who knows what other media will prove better than cable for a broadcast network; maybe radio or telephone circuits, or power wiring or frequency-multi-plexed CATV, or microwave environments, or even combinations thereof.

The essential feature of our medium -- the ether -- is that it carries transmissions, propagates bits to all stations. We are to investigate the applicability of ether networks.



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ETHER ACQUISITION

HOW DOES A STATION'S TRANSMITTER ACQUIRE THE USE OF THE ETHER FOR A PARTICULAR TRANSMISSION? THERE ARE MANY POSSIBLE WAYS.

THE ALOHA RADIO NETWORK USES WHAT WE CALL "DE FACTO" ETHER ACQUISITION. A STATION DESIRING TO TRANSMIT SIMPLY DOES, IT JUMPS RIGHT ON AND USES THE ETHER. IF THE TRANSMISSION GOES THROUGH, THE ETHER HAS BEEN SUCCESSFULLY ACQUIRED, DE FACTO. IF SOME OTHER TRANSMISSION CONFLICTS, THEN BOTH (ALL) ARE LOST AND ARE RETRIED SOME RANDOM TIME LATER; THE ETHER HAS FAILED TO BE ACQUIRED.

AT LEAST TWO FACTS ABOUT THE ALOHA ETHER AND TRANSCEIVERS SUPPORT THE USE OF DE FACTO ETHER ACQUISITION. FIRST, THE ALOHA ETHER IS VERY BIG, IT TAKES A LONG TIME FOR TRANSMISSIONS TO PROPAGATE; AND SECOND, ALOHA TRANSCEIVERS ARE STRICTLY HALF-DUPLEX, THEY CANNOT DETECT INTERFERENCE WHILE TRANSMITTING. NEITHER OF THESE TWO FACTS IS TRUE OF OUR ETHER OR OUR STATIONS AS THEY ARE ENVISIONED.

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AND NOW, FOUR AXIOMS:

$\boxed{\text{Axioms?}}$

(1) THE ETHER AXIOM: THE ETHER CARRIES TRANSMISSIONS TO ALL STATIONS.

(2) THE PROXIMITY AXIOM: PROPAGATION TIMES ARE SOMEWHAT SMALL.

(3) THE DETECTION AXIOM: STATIONS CAN DETECT, AT ALL TIMES, TRANSMISSIONS OF OTHER STATIONS, AS THEY PASS, IN ABOUT ONE BIT TIME.

(4) THE DEFERENCE AXIOM: WHILE DETECTING A PASSING TRANSMISSION, NO STATION WILL BEGIN OR CONTINUE ITS OWN TRANSMISSION.

NOT THE LOCAL NETWORK!

THE ETHER AXIOM FREES US FROM CONSIDERING NETWORK ROUTING. THE PROXIMITY AXIOM ALLOWS US TO CONSIDER SOLUTIONS WHICH WOULD BE TOTALLY IMPRACTICAL OTHERWISE — SAY AS IN ALOHA RADIO. THE DETECTION AXIOM DOES NOT IMPLY THAT CONFLICTS CAN BE AVOIDED; SEPARATED TRANSCEIVERS CAN BEGIN TRANSMISSION ON FREE ETHER ONLY TO DISCOVER LATER THAT THEIR TRANSMISSIONS HAVE COLLIDED ELSEWHERE. THE DEFERENCE AXIOM FOLLOWS FROM NOTHING MORE THAN OUR BASIC INTUITION — MAYBE IT SHOULD BE DISCARDED SOMETIME..

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AND NOW, A DEFINITION:

A STATION IS SAID TO HAVE ACQUIRED THE ETHER WHEN AND ONLY WHEN IT HAS BEGUN TRANSMITTING A PACKET AND ALL OF THE OTHER STATIONS HAVE DETECTED THE TRANSMISSION AND ARE DEFERRING TO IT.

AFTER ACQUIRING THE ETHER, A STATION IS SAID TO HOLD THE ETHER AS LONG AS IT CONTINUES TRANSMITTING.

THE DEFERENCE AXIOM IMPLIES THAT ONCE A STATION HAS ACQUIRED THE ETHER, IT CAN HOLD THE ETHER AS LONG AS IT WANTS, USING IT WITHOUT CONFLICT FOR THE DURATION OF ITS TRANSMISSION. A STATION VIOLATING THE DEFERENCE AXIOM COULD, OF COURSE, BREAK A HOLD ON THE ETHER AND ACQUIRE IT, BUT FOR THE MOMENT WE DISALLOW THIS BEHAVIOR.

IF THE ETHER IS TO BE SHARED IN SOME REASONABLE WAY, THEN FURTHER AGREEMENTS WILL BE REQUIRED TO REGULATE THE MAXIMUM HOLDING TIME. BUT THIS COMES LATER.

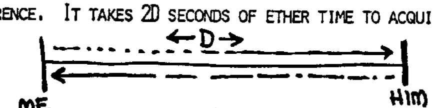
And now, another so-called axiom:

(5) The diameter axiom: For any given Ether network, there exists a diameter D, the propagation delay between most distant stations, the maximum time from start of transmission to detection of transmission by a distant station.

By the proximity axiom, D is "somewhat" small.

And now a fact:

How long after beginning transmission must I detect no conflict before I can be certain that I have acquired the Ether? The answer: 2D, one round trip. Say that there is this station at the far end of the Ether, D seconds away. After I start transmission on the open Ether, it can be D seconds before he knows about it. But if just before my transmission reaches him he decides to transmit himself, then it will be D more seconds before I find out about it — it can be 2D seconds before I sense conflict and therefore failure to acquire. He will have sent a bit or two before detecting my transmission and will defer, but it's too late. His brief transmission will cause me to let go of the Ether according to the axiom of deference. It takes 2D seconds of Ether time to acquire.



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DEFINITION: A TRANSMISSION IS SAID TO BE <u>CONFLICT-FREE</u> WITH RESPECT TO ITS TRANSMITTER AND A SPECIFIED RECEIVER (DISREGARDING ETHER NOISE) IF AND ONLY IF THE TRANSMISSION PLACED ON THE ETHER BY THE TRANSMITTER IS LATER CORRECTLY RECEIVED (I.E., WITHOUT INTERFERENCE) AT THE RECEIVER.

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FACT: IF THE ETHER IS ACQUIRED FOR A TRANSMISSION, THEN THE TRANSMISSION IS CONFLICT-FREE FOR ALL RECEIVERS.

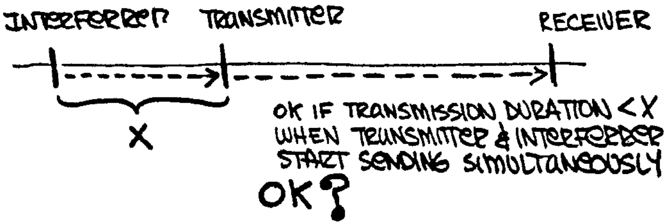
FACT: ETHER ACQUISITION IS NOT NECCESSARY FOR CONFLICT-FREE TRANSMISSIONS, EVIDENCE ALOHA SUB-ACQUISITION TRANSMISSIONS.

FACT: THE LONGEST CONFLICT-FREE SUB-ACQUISITION TRANSMISSION IS D SECONDS LONG.

OK?

FACT: A TRANSMISSION OF ANY LENGTH D (EVEN LESS THAN D) CAN BE DETERMINED TO BE CONFLICT-FREE FOR ALL RECEIVERS BY ITS TRANSMITTER IF NO CONFLICTING TRANSMISSIONS ARE DETECTED FOR A PERIOD OF 2D SECONDS AFTER THE START OF TRANSMISSION.

FACT: A TRANSMISSION MAY BE CONFLICT-FREE WITH RESPECT TO ITS INTENDED RECEIVER EVEN IF AN OTHER TRANSMISSION IS DETECTED BEFORE THE 2D SAFETY PERIOD.



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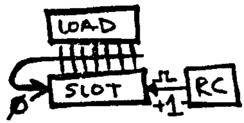
ETHER BARGAINING LOGIC

WE PRESUME WE KNOW THE ETHER'S DIAMETER AND THAT IT IS SMALL. WE PROPOSE THE FOLLOWING LOGIC FOR A STATION'S BARGAINING WITH THE ETHER.

FIRST, A CLOCK; CALL IT THE ROUND-TRIP CLOCK (RC). THE RC NEED NOT BE VERY GOOD; AN UGLY MULTI-VIBRATOR PERHAPS. IT SHOULD HAVE A PERIOD OF 2D+EPSILON, FOR SOME SMALL EPSILON.

SECOND, A COUNTER; CALL IT THE SLOT COUNTER (SC). THE SC IS ALWAYS COUNTING UP, INCREMENTED BY THE ROUND-TRIP CLOCK.



THIRD, A REGISTER; CALL IT THE LOAD REGISTER (LR). THE LOAD REGISTER TELLS THE SLOT COUNTER WHEN TO RETURN TO ZERO. THE LR HOLDS A NUMBER WHICH IS A MEASURE OF ETHER TRAFFIC LOAD. IN COUNTING UP FROM ZERO, THE SLOT COUNTER RETURNS TO ZERO WHEN ITS CONTENTS ARE EQUAL TO THAT OF THE LOAD REGISTER. THE LOAD REGISTER DEFINES THE LENGTH OF THE SLOT COUNTERS CYCLE.

FOURTH, OTHER-DRIVE DETECTOR, OD. THE OD LOOKS AT THE ETHER TO DETECT WHEN THE ETHER IS BEING DRIVEN BY SOME TRANSMITTER OTHER THAN ITS OWN, AT THE POINT OF THE TRANSMITTER.

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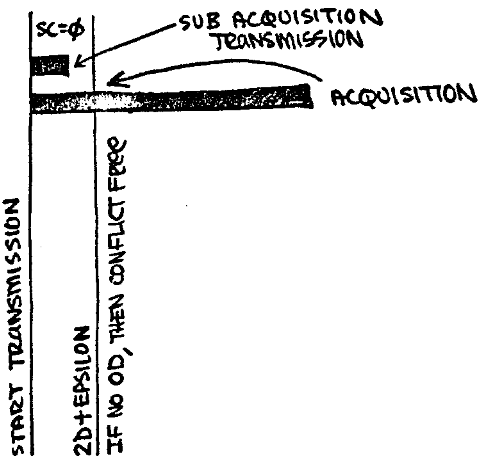
FIFTH, THE OTHER-DRIVE DETECT BIT; ODB. THIS FLIP-FLOP IS SET WHENEVER THE OTHER-DRIVE DETECTOR DETECTS SOME OTHER TRANSMITTER'S DRIVE ON THE ETHER. BY THE DEFERENCE AXIOM, THE SETTING OF THE ODB CAUSES ANY TRANSMISSION IN PROGRESS TO BE IMMEDIATELY ABORTED. (THE ODB IS CLEARED WITH EACH TICK OF THE ROUND-TRIP CLOCK.)

SIXTH, THE NO-CONFLICT BIT, NCB. THIS FLIP-FLOP IS SET WITH THE FIRST BIT OF A TRANSMISSION ONTO THE ETHER BY THE LOCAL TRANSMITTER. THIS BIT IS CLEARED BY THE OTHER-DRIVE DETECTOR, ONLY DURING THE FIRST ROUND-TRIP OF A TRANSMISSION -- ONLY WHILE THE SLOT COUNTER IS ZERO.



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WHEN A STATION DESIRES TO TRANSMIT, IT WAITS UNTIL THE ETHER IS EMPTY AND THE SLOT COUNTER IS ZERO. IT THEN BEGINS TRANSMISSION, THE PLACING OF BITS INTO THE ETHER.

IF THE OTHER-DRIVE BIT COMES ON BEFORE END-OF-TRANSMISSION, THEN THE TRANSMISSION IS ABORTED -- THE DEFERENCE AXIOM. (WE MIGHT RECONSIDER THIS POSITION — THE CONFLICTING TRANSMISSION MAY BE GOING IN THE OTHER DIRECTION). ?

AT THE START OF ACTUAL TRANSMISSION, THE NO-CONFLICT BIT IS SET. IF THAT BIT IS SET AT THE FIRST TICK OF THE ROUND-TRIP CLOCK, THEN A CONFLICT-FREE TRANSMISSION HAS OCCURRED. THIS EVENT MAY BE SIGNALED DURING TRANSMISSION IF THE TRANSMISSION IS LONGER THAN 2D SECONDS, OR AFTER THE END OF TRANSMISSION, IF THE TRANSMISSION IS LESS THAN 2D LONG. THUS THE STATION CAN KNOW TO SOME HIGH PROBABILITY THAT ITS TRANSMISSION HAS SUCCEEDED. (DISREGARDING NOISE)

The slot counter has the following purpose. As an ongoing transmission comes to an end, all the waiting stations will want to jump on with their transmissions -- and these will often conflict -- more often with load. The slot counters in the various stations will tend not to be synchronized so that the slot counters will hold off some of the stations giving (hopefully) one of them time to acquire the ether. (OR JUST USE IT) For short transmissions, acquisition will not occur and the ether will experience rapid transmissions, hopefully one per "slot". For long transmissions, the first station to the ether will acquire it, thus queueing up the other stations to wait their turn.

In the event that a conflict is detected, the station has two options. First, it can clobber its slot counter RANDOMLY to move it around in the queueing cycle; after a while the terminals should become distributed over the various slots of the load cycle. Or, the station might choose to, in addition, increment[redacted] the contents of the load register, to reduce its load on the ether. As the ether becomes more loaded with traffic, all of the stations will therefore back off to share the ether 'optimally'. Of course, with success on the ether, stations must consider reducing the contents of the load register, to tighten up in the face of reduced traffic.

A STATION CAN BEGIN TRANSMISSION IN A SLOT WITH PROBABILITY $\frac{1}{\text{LOAD}}$.

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