Scaling CSMA/CD to 1000 Mb/s
An Update

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Outline

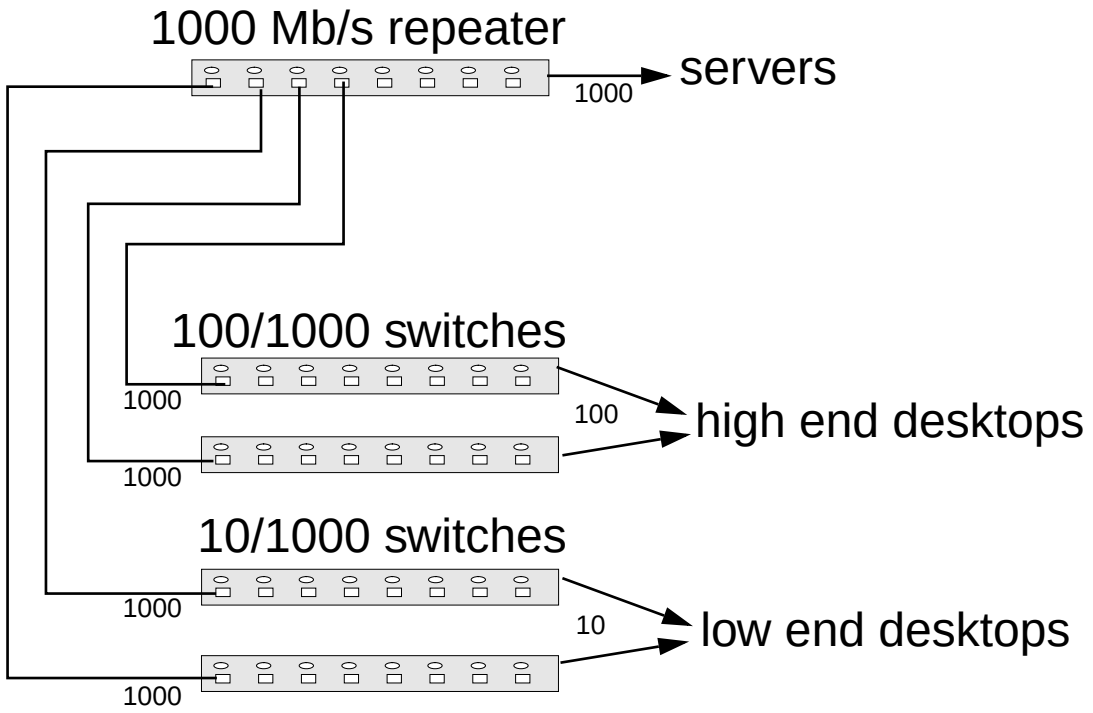
- Introduction
- Topologies
- Bit Budget
- Issues
- Solution
- Impact on MAC
- MAC Parameters
- Performance
- Possible refinements
- Conclusions

Introduction

- Scaling CSMA/CD to 1000 Mb/s is a good idea
  - Widely implemented, well understood protocol
  - Demonstrated low cost at 10 and 100 Mb/s
  - Cost benefit of 1000 Mb/s shared versus 1000 Mb/s switched
- Scaling CSMA/CD to 1000 Mb/s is slightly more complicated than scaling it to 100 Mb/s
  - Wire delays are 10x larger (in BT) than at 100 Mb/s
  - “shift the decimal point” approach results in a ridiculously small collision domain diameter
- Backwards compatibility with 10 and 100 Mb/s is essential

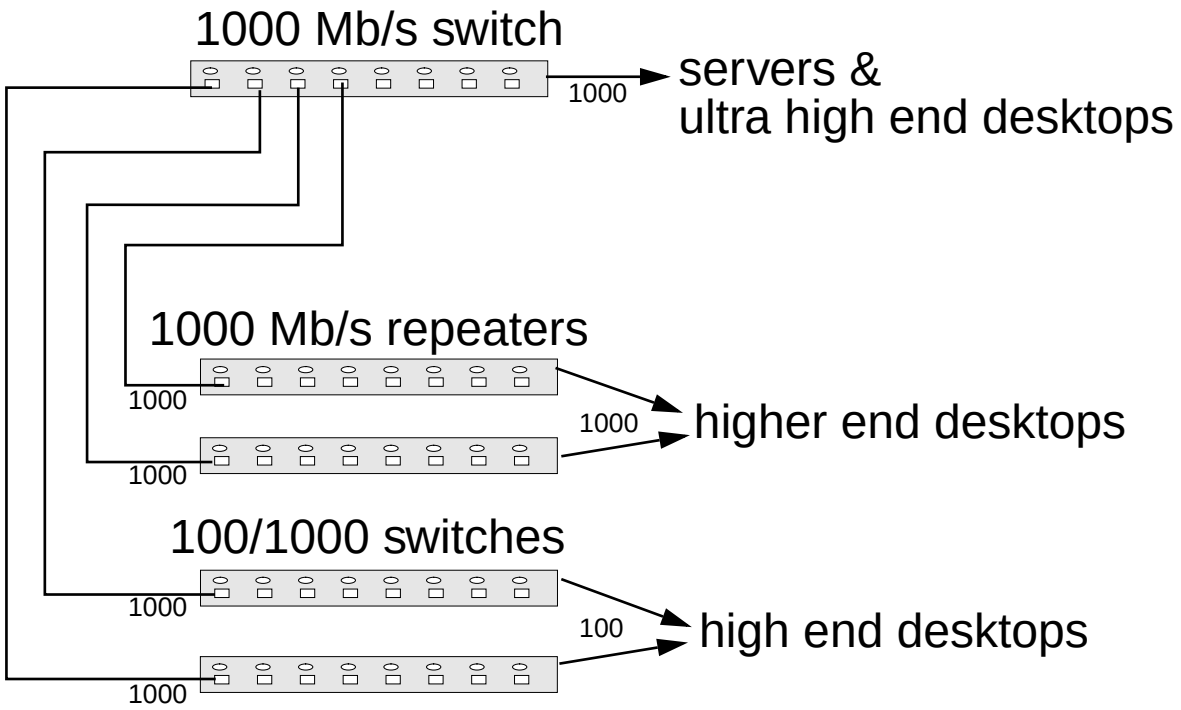
Topologies

- **Most useful CSMA/CD topologies have at least one repeater**



CSMA/CD used in a single repeater collision domain
within a server room

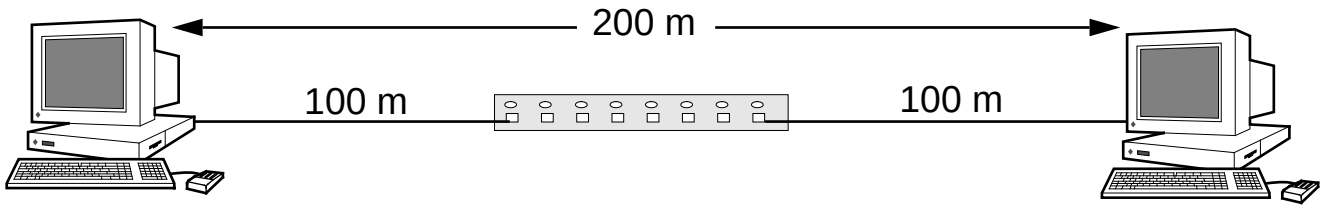
Topologies (cont)



CSMA/CD used in single repeater collision domains
with 1000 Mb/s horizontal runs

Topologies (cont)

- **Horizontal runs are 100 meters maximum**
- **A CSMA/CD topology with horizontal runs out to desktops must support a diameter of at least 200 meters**



Bit Budgets

- Bit budget calculations are highly dependent on:
  - Physical layer signalling method and architecture
  - MAC <=> PHY data path width
  - MAC state machine frequency
  - Repeater data path width
  - Repeater state machine frequency
  - Fairness issues
- See Stephen Haddock's presentation for an updated bit budget analysis

Bit Budgets (cont)

- Conclusions from bit budget analysis
  - Cable delay dominates, but even with short cables, the bit budget exceeds 512 BT
  - DTE and repeater delay estimates may be optimistic
  - The minimum frame size must be increased from 512 bits to achieve useful topologies at 1000 Mb/s
- Recommend a new minimum frame size of 512 Bytes
  - Simply change bits to bytes!

Issues

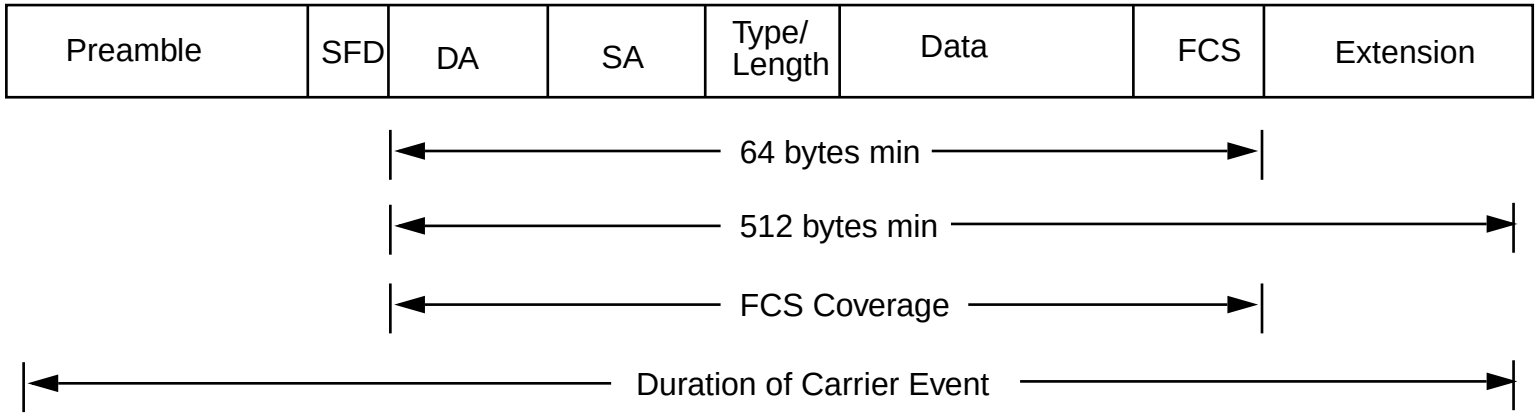
- It’s not that simple
- Trying to solve the problem by increasing the minFrameSize to 512 Bytes has harmful side effects
  - Degrades maximum small packet rate on full duplex links where it is not necessary to use the larger minimum size
  - Can’t propagate the inflated packets to 100 Mb/s or 10 Mb/s networks, the performance loss would be hideous
  - Can’t rely on the padding/stripping mechanism in the 802.3 MAC when using protocol stacks which use the Ethernet frame format
- Must find a way to extend the minimum frame size only on 1000 Mb/s, CSMA/CD networks, regardless of whether Ethernet or 802.3 frame format is used

Solution

- Conceptually, extend the duration of the carrier event without extending the data field, or altering the FCS field
- Introduce a new mechanism which appends non-data symbols to the end of short frames
- Extend the collision window to include these symbols
- Include the extension in the fragment discard calculation
- Remove the extension before checking the FCS and passing the frame to LLC

Solution (cont)

- **Frame extension**



- **The extension symbols are non-data symbols, and are recognized as such by the MAC and the PHY**
- **The extension starts on an octet boundary, and is an integer number of octets in length**

Impact on MAC

- **New const (4.2.7.1)**

  const

  extendSize = ...; {in bits, implementation-dependent, see 4.4}
  extensionBit = ...; {a new type of non-data bit}

- **New Transmit State Variable (4.2.7.2)**

  var

  extension:0..extendSize; {length of extension}

- **New Receive State Variable (4.2.7.3)**

  var

  extendCount: 0..extendSize; {count of extension bits at end of frame}

Impact on MAC

- **Mod to StartTransmit (4.2.8)**

```
procedure StartTransmit;
begin
   extension := 0;
   currentTransmitBit := 1;
   lastTransmitBit := frameSize;
   transmitSucceeding := true;
   transmitting := true;
   lastHeaderBit := headerSize
end; {StartTransmit}
```

- **Mod to StartReceive (4.2.9)**

```
procedure StartReceive;
   begin
        currentReceiveBit :=1;
        extendCount := 0;
        receiving := true
   end; {StartReceive}
```

Impact on MAC (Transmitter)

- **Mod to BitTransmitter (4.2.8)**

```
process BitTransmitter;
begin
   cycle {outer loop}
        if transmitting then
        begin {inner loop}
             if halfDuplex then (extension : = minFrameSize + extendSize);
             PhysicalSignalEncap; {send preamble and sfd}
             while transmitting do
             begin
                if currentTransmitBit > lastTransmitBit then
                     TransmitBit(extensionBit)
                else
                     TransmitBit(outgoingFrame[currentTransmitBit]);
                if newCollision then StartJam else NextBit
             end;
        end; {inner loop}
   end; {outer loop}
end; {BitTransmitter}
```

Impact on MAC (Transmitter)

- **Mod to NextBit (4.2.8)**

```
procedure NextBit;
  begin
      currentTransmitBit := currentTransmitBit + 1;
      transmitting := ((currentTransmitBit ≤ lastTransmitBit)
                          or (currentTransmitBit ≤ extension))
  end; {NextBit}
```

- **Mod to StartJam (4.2.8)**

```
procedure StartJam;
  begin
      currentTransmitBit := 1;
      lastTransmitBit := jamSize;
      extension := 0;
      newCollision := false
  end; {StartJam}
```

Impact on MAC (Transmitter)

- **Mod to WatchForCollision (4.2.8)**

```
procedure WatchForCollision;
begin
   if transmitSucceeding and collisionDetect then
   begin
        if currentTransmitBit > (minFrameSize - headerSize + extendSize) then
             lateCollisionError := true;
        newCollision:= true;
        transmitSucceeding := false
   end
end {WatchForCollision}
```

Impact on MAC (Receiver)

- **Mod to BitReceiver (4.2.9)**

```
process BitReceiver;
   var b: Bit;
begin
   cycle {outer loop}
        while receiving do
        begin {inner loop}
        if currentReceiveBit = 1 then
             PhysicalSignalDecap; {strip off the preamble and sfd}
             b := ReceiveBit; {get next bit from physical Media Access}
             if receiveDataValid then
                if b = extensionBit then
                extendCount := extendCount + 1
                else
                begin {append bit to frame}
                     incomingFrame[currentReceiveBit] := b;
                     currentReceiveBit := currentReceiveBit + 1
                end
        receiving := receiveDataValid
        end {inner loop}
        frameSize := currentReceiveBit - 1 + extendCount
   end {outerloop}
end; {BitReceiver}
```

Impact on MAC (Receiver)

- **Mod to ReceiveLinkMgmt (4.2.9)**

```
procedure ReceiveLinkMgmt;
begin
   repeat
        StartReceive;
        while receiving do nothing; {wait for frame to finish arriving}
        excessBits := frameSize mod 8;
        frameSize := frameSize - excessBits; {truncate to octet boundary}
        if halfDuplex then
        begin
             receiveSucceeding :=((frameSize ≥ (minFrameSize + extendSize));
             frameSize := frameSize - extendCount
        end
        else
             receiveSucceeding := (frameSize ≥ minFrameSize);
   until receiveSucceeding
end;
```

MAC Parameters

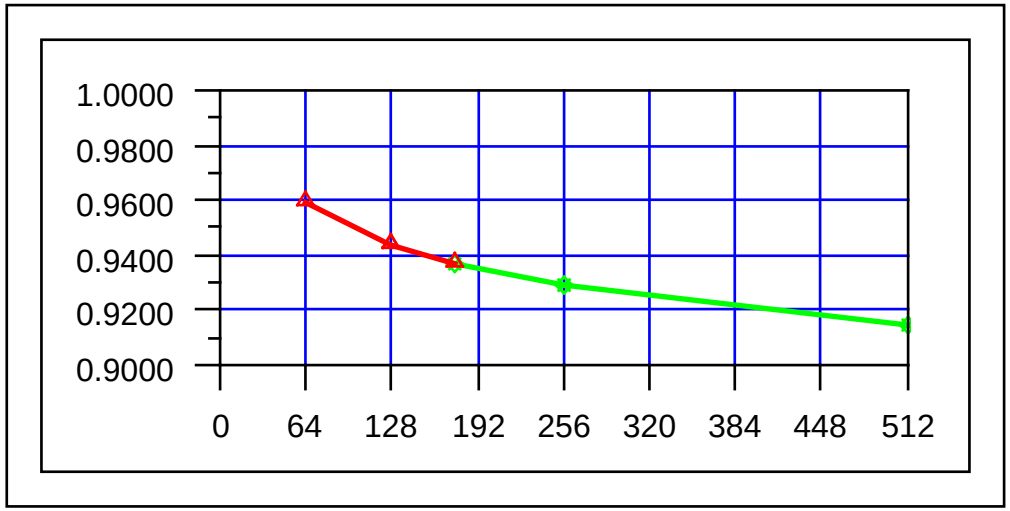
- **New Parameter Table 4.4.2.4**

Parameters	Values
slotTime	4096 bit times
interFrameGap	96 ns
attemptLimit	16
backoffLimit	10
jamSize	32 bits
maxFrameSize	1518 octets
minFrameSize	512 bits (64 octets)
addressSize	48 bits
extendSize	448 octets

Performance

- **Experimental and simulation results presented in La Jolla (4 node scaled 100BASE-FX using 1500 byte UDP packets)**

diameter	200	800	1200	1600	2000
slottime	64	128	174	256	512
txpps	7805.66	7681.15	7626.95	7560.00	7440.00
rxpps	7803.63	7691.94	7634.31	7560.00	7440.00
colps	4835.01	2641.13	1940.92	1420.00	800.00
oerrps	123.45	61.25	46.08	30.00	15.00
udput	0.9592	0.9439	0.9372	0.9289	0.9142
colut	0.0325	0.0313	0.0301	0.0313	0.0340

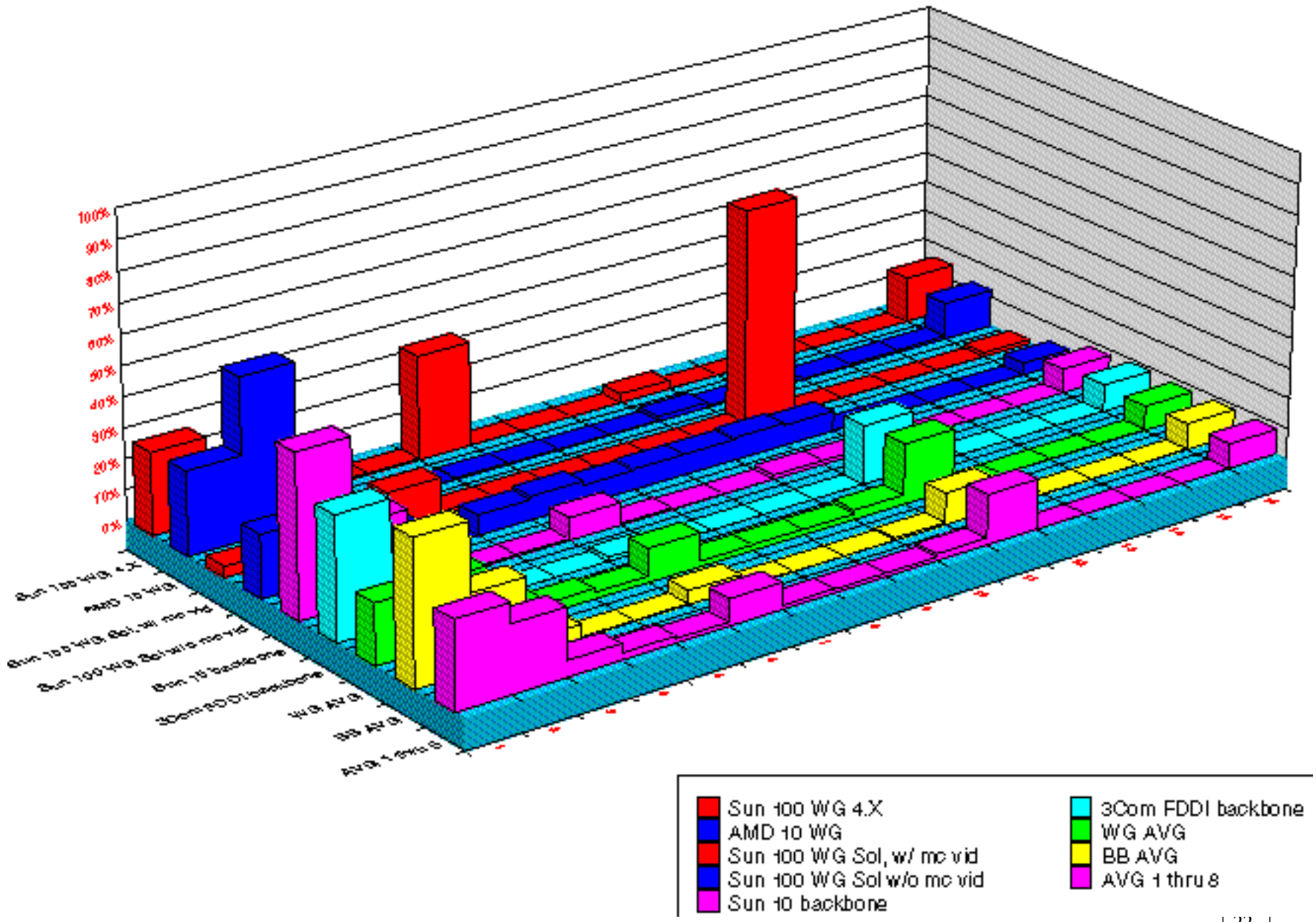


Performance (cont)

- **Subsequent simulations used “workgroup average” packet size distribution derived from some “real world” sampling**

100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600 □		Packet Size (less than)
.269	.079	.119	.006	.004	.343	.000	.000	.000	.029	.000	.000	.001	.000	.000	.151	1	Sun 100 WG 4.X
.275	.527	.012	.005	.003	.006	.004	.002	.003	.016	.005	.002	.004	.008	.009	.123	2	AMD 10 WG
.037	.039	.013	.121	.010	.012	.010	.010	.010	.010	.714	.000	.000	.001	.000	.014	3	Sun 100 WG Sol, w/ mc vid
.206	.190	.088	.002	.066	.076	.062	.066	.066	.072	.066	.000	.000	.000	.000	.039	4	Sun 100 WG Sol w/o mc vid
.530	.252	.018	.004	.005	.074	.005	.002	.001	.013	.012	.001	.001	.001	.001	.081	5	Sun 10 backbone
.402	.236	.066	.000	.000	.014	.000	.000	.000	.000	.192	.000	.000	.000	.000	.090	6	3Com FDDI backbone
.197	.209	.058	.034	.021	.109	.019	.020	.020	.032	.196	.001	.001	.002	.002	.082	7	WG AVG
.466	.244	.042	.002	.003	.044	.003	.001	.001	.007	.102	.001	.001	.001	.001	.086	8	BB AVG
.286	.220	.053	.023	.015	.087	.013	.013	.013	.023	.165	.001	.001	.002	.002	.083	9	AVG 1 thru 8

- **See Mohan Kalkunte’s presentation from Wakefield for simulation results using “workgroup average” packet size distribution**


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Sun 100 WG 4.X
AMD 10 WG
Sun 100 WG Sol, w/ mc vid
Sun 100 WG Sol w/o mc vid
Sun 10 backbone
3Com FDDI backbone
WG AVG
BB AVG
AVG 1 thru 8

Possible refinements

- **Reduce** backoffLimit **to 9, 8, or 7**
  - **See Stephen Haddock's presentation from Wakefield**
  - **Assume smaller number of nodes per collision domain**
  - **?Should mitigate "Capture Effect"?**
  - **?May increase aggressiveness, and hence the amount of bandwidth consumed by collision events?**
- **Packet Packing**
  - **See Stephen Haddock's presentation from Wakefield**
  - **Stations send several small packets in one slot time**
  - **?Should improve utilization?**
  - **?May complicate receiver and transmitter?**
- **"Virtual Collisions"**
  - **See Moti Weizman's presentation**
  - **?Would reduce** extendSize **and** slotTime**?**
  - **?May hurt fairness?**

Conclusions

- Useful CSMA/CD networks can be built at 1000 Mb/s
- The performance of the baseline proposal is adequate for workgroup applications
- Several proposals for possible refinements can be evaluated