A Short Tutorial on CSMA

- Related work and history
- Analytical results
- Ethernet & measured results
- Pros and Cons

What this Is

- Presentation of established work in the field
- Highlights of well-known work

What this is Not

- A pitch for CSMA
- Attempt to apply these or other results to 802.11 work (merits a separate submission)

Context for CSMA Discussion[1]

Definitions -

Autonomous Networks

networks operated by independent entities not actively coordinated with each other

Collocated Networks

networks operating on the same physical channel in the same vicinity

Basic System and Market Assumptions

- A *few* cells will exist
- The system architecture should exploit the existence of cells to the maximum extent possible

but

- There will not be enough cells to guarantee every autonomous collocated network exclusive use of a cell
- Users will not accept a solution that requires coordinated network engineering by unrelated collocated users

it follows that

- Spectrum sharing among user communities or independent access points using a common cell/channel is an essential requirement for the system architecture.

Consequently, 2 channel access issues exist

- To regulate channel sharing by autonomous collocated networks
- To regulate channel sharing by nodes within an autonomous system

Any proposed system architecture must address both issues to be viable

[1]This introductory section does not form part of the Tutorial since it represents the opinions of the author.

Context for CSMA discussion, contd

Why propose CSMA?

- A serious contender
- Well suited to small cells and work-groups
- Supports cooperative spectrum use between independent systems
- Supports portable computer environments well (dynamic topologies)

History and Related Work

History of CSMA

- First proposed in 1971 for use in packet radio channels
- Research funded by DoD for use in Packet Radio
- The Darpa Packet Radio Network (PRNET) is CSMA based
- Use in packet radio preceded use in wired networks

CSMA and related protocols

- Aloha
- CSMA
- Ethernet/802.3

Conceptual basis

- The channel carries its own control information
- Control is distributed among all nodes

References

The research of L. Kleinrock, F. Tobagi, S. Lam et al

Primary source materials for this presentation:

"Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi

"Packet Switching in Radio Channels: Part II- The hidden terminal problem in Carrier Sense Multiple Access and the busy tone solution"
by Tobagi and Kleinrock

Unless otherwise stated, all graphs are reproduced from these sources.

Analytical Results

- System assumptions
- non-persistent CSMA
- p-persistent CSMA
- 1-persistent CSMA

System Assumptions (basis for analysis)

- Wideband channel
- Propagation delay a small fraction of packet transmission time
- Fixed length packets
- Infinite population
- Independent Poisson source of packets
- Retransmissions increase the offered load on the channel
- Half-duplex nodes
- Channel noiseless
- Propagation delay is identical for all source-destination pairs
- No capture (overlap causes destruction of all transmitted pkts)

Simulation results

- in agreement with analytic results

Aloha protocols

- **Aloha**
  Node transmits whenever it has a packet ready
  (total chaos model!)

- **Slotted Aloha**
  Node transmits when it has a packet ready, but only on time slot boundaries

Performance

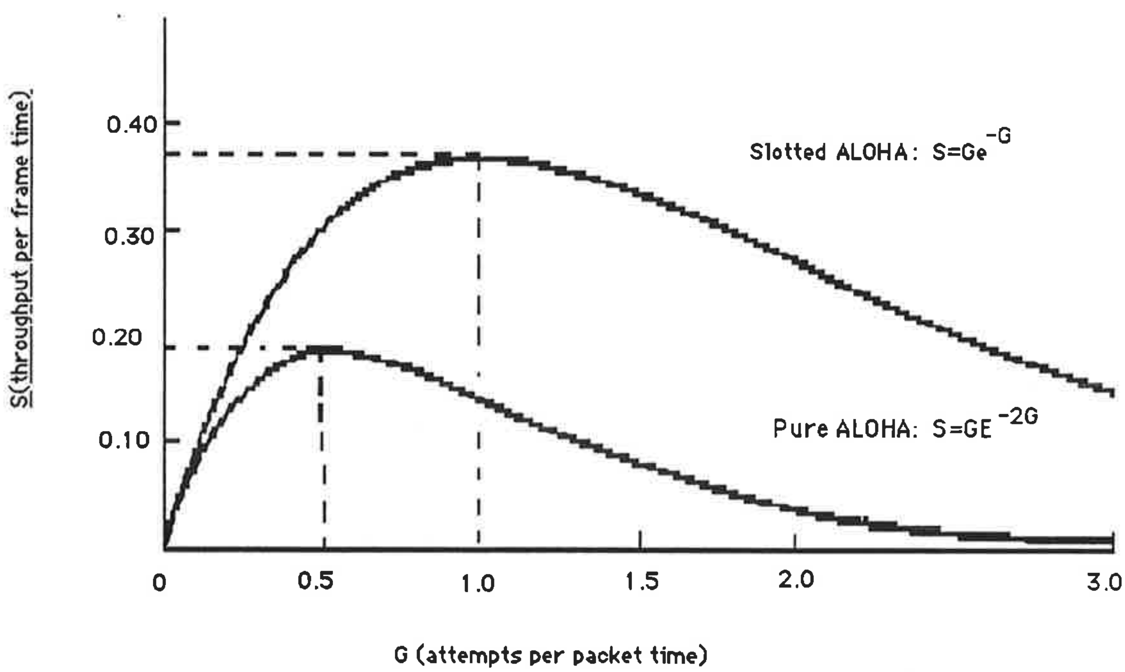

Fig. 3-3. throughput versus offered traffic for ALOHA systems.

CSMA protocols

- **Sense the channel before transmitting**
- **Execute a channel-state-dependent algorithm**
- **Different algorithms yield different "CSMA-class" protocols**
- **Main variants**
  - **non-persistent**
  - **p-persistent**
  - **1-persistent**
  - **Ethernet (1-persistent with *collision detect*)**
- **Important parameter:**
  The *collision window* caused by propagation delay
  Normalized collision window is defined as

$$a = \frac{\text{Propagation time}[2]}{\text{Packet transmission time}}$$

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[2]In practice,
Effective propagation time = actual propagation time + carrier sense time + rcv-xmt turn-around time
and is dominated by the carrier sense and rcv-xmt turn-around times.

If carrier sense time < 10 µsec
rcv-xmt turnaround time < 10 µsec
(these are good representative numbers)
then effective propagation time ª 20 µsec

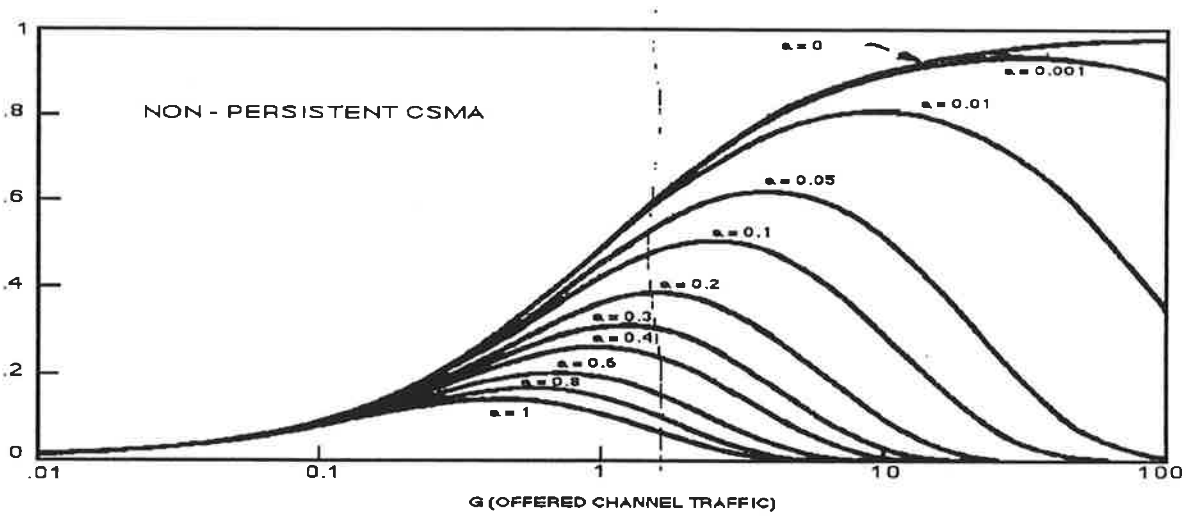
If data rate = 1 Mb/s, range = 50m, packet length = 1000 bytes (8000 bits) -
a = 0.0025
If data rate = I Mb/s, range = 50m, packet length = 100 bytes (800 bits) -
a = 0.025

Non-persistent CSMA

Algorithm:

Sense the channel before transmitting.
If channel idle, transmit
If channel busy, backoff, then repeat entire algorithm (sense + transmit/wait)
Backoff algorithm is usually exponential

Performance curves



Throughput in nonpersistent CSMA.

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

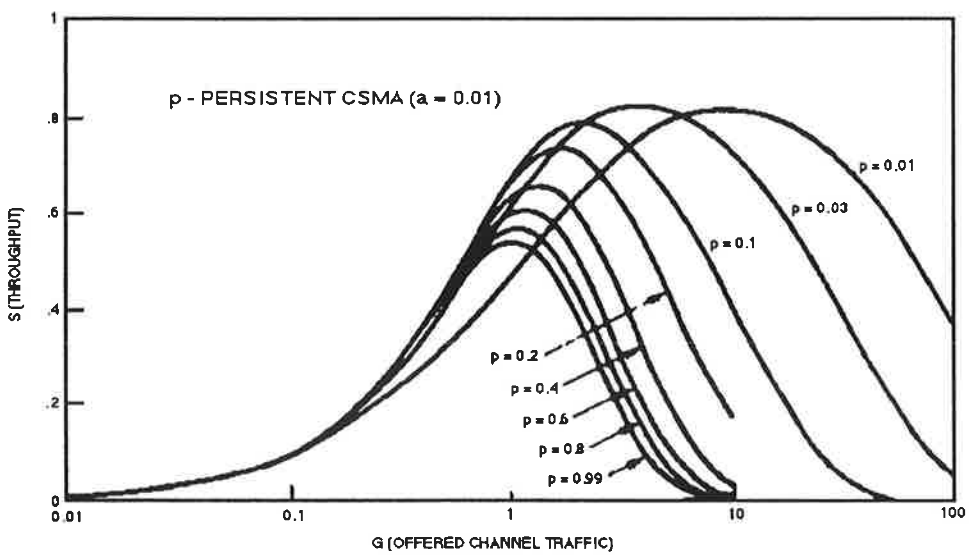
p-persistent CSMA

- Assumes a very fine-grained slotted channel
- If p = 1 protocol similar to 1-persistent CSMA
- p=0 *is not the same as non-persistent CSMA*

Algorithm:

Sense the channel before transmitting on mini-slot boundaries
If busy, wait till channel goes idle
If idle, transmit with probability p
Else wait for the next mini-slot, and repeat.

Performance curves



Channel throughput in p - persistent CSMA.

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

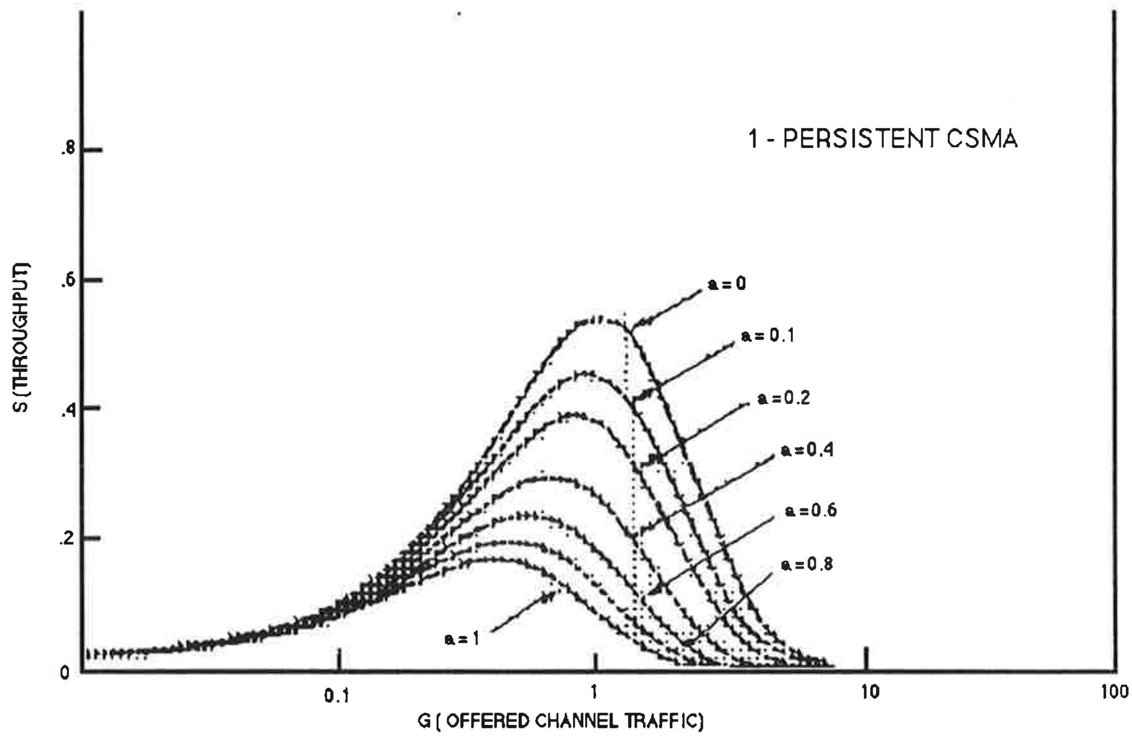
1-persistent CSMA

Algorithm:

Sense the channel before transmitting on mini-slot boundaries
If idle, transmit
If busy, wait till channel goes idle and then transmit

- Collision *will occur* if > 1 node ready to transmit during a packet transmission time
- Ethernet/802.3 is 1-persistent *with Collision Detect.*

Performance curves



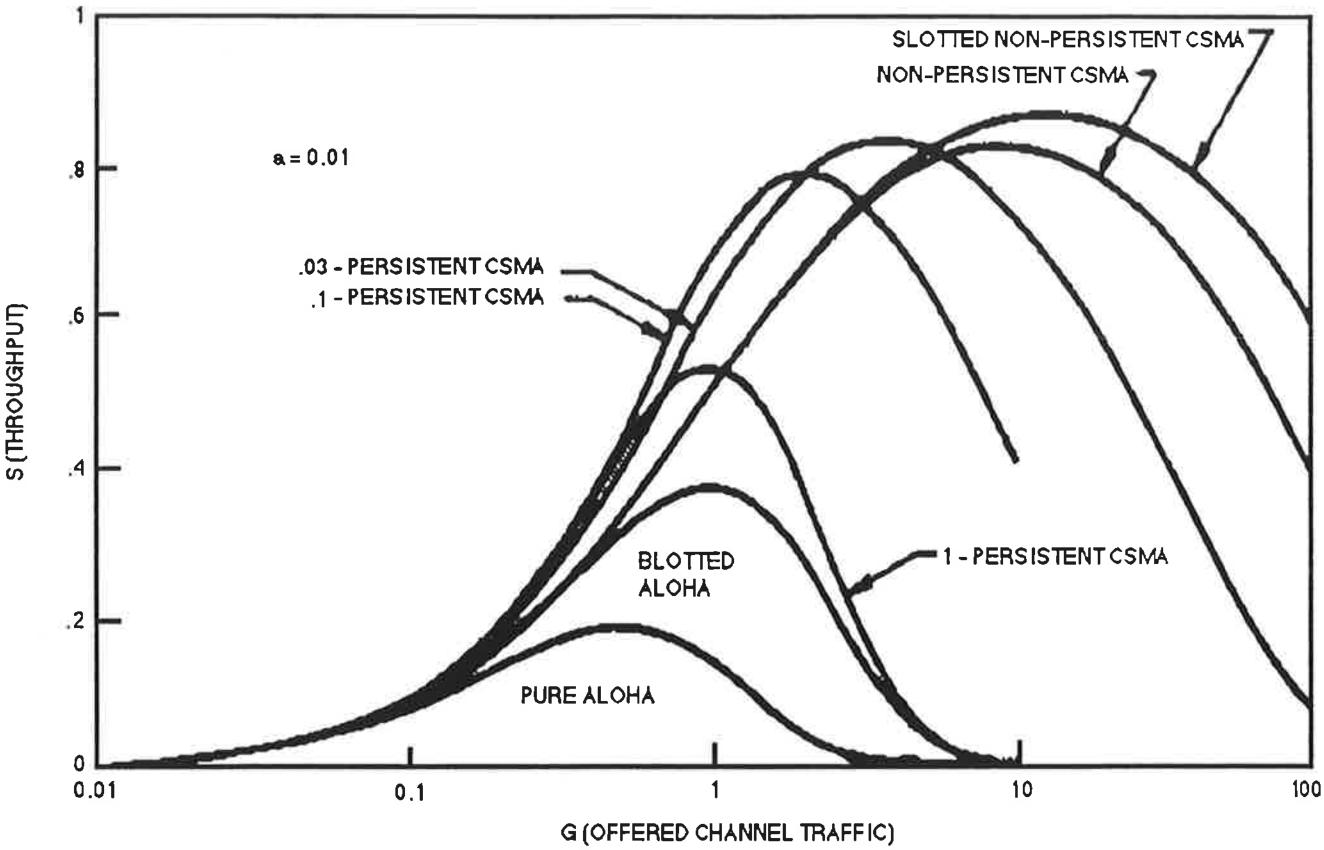
Throughput in 1-persistent CSMA.

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

CSMA throughput determinants and characteristics

- Access mode
- Propagation Delay
- p in p-persistent CSMA

Access mode



Throughput for the various access modes (a = 0.01)

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

Propagation Delay

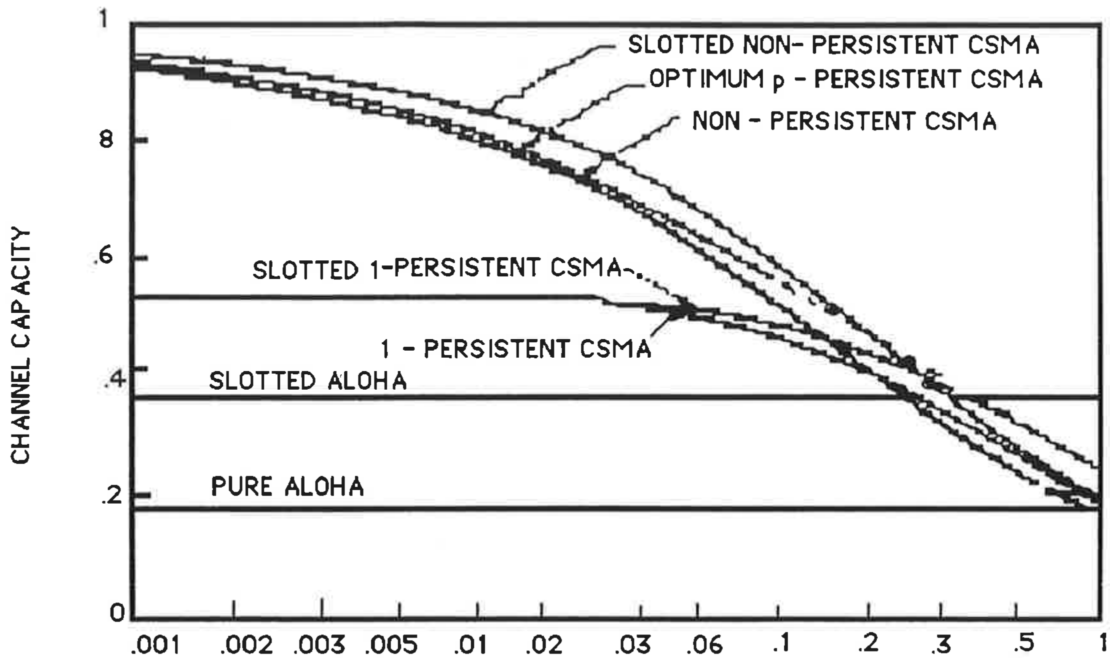
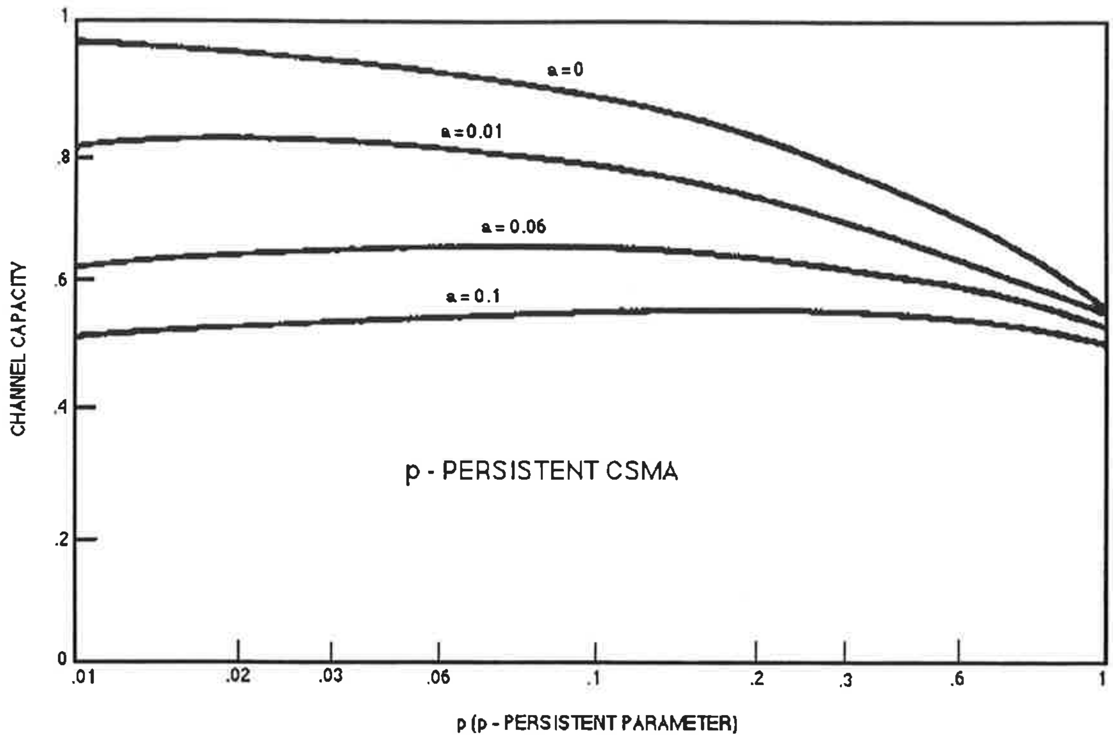


FIG. 10. EFFECT OF PROPAGATION DELAY ON CHANNEL CAPACITY.

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

p in p-persistent CSMA



p - persistent CSMA: effect of p on channel capacity.

Source: "Packet Switching in Radio Channels: Part I - Carrier Sense Multiple-Access Modes and their Throughput-Delay Characteristics" by Klenirock and Tobagi, IEEE Trans on Comm Dec 75

Ethernet

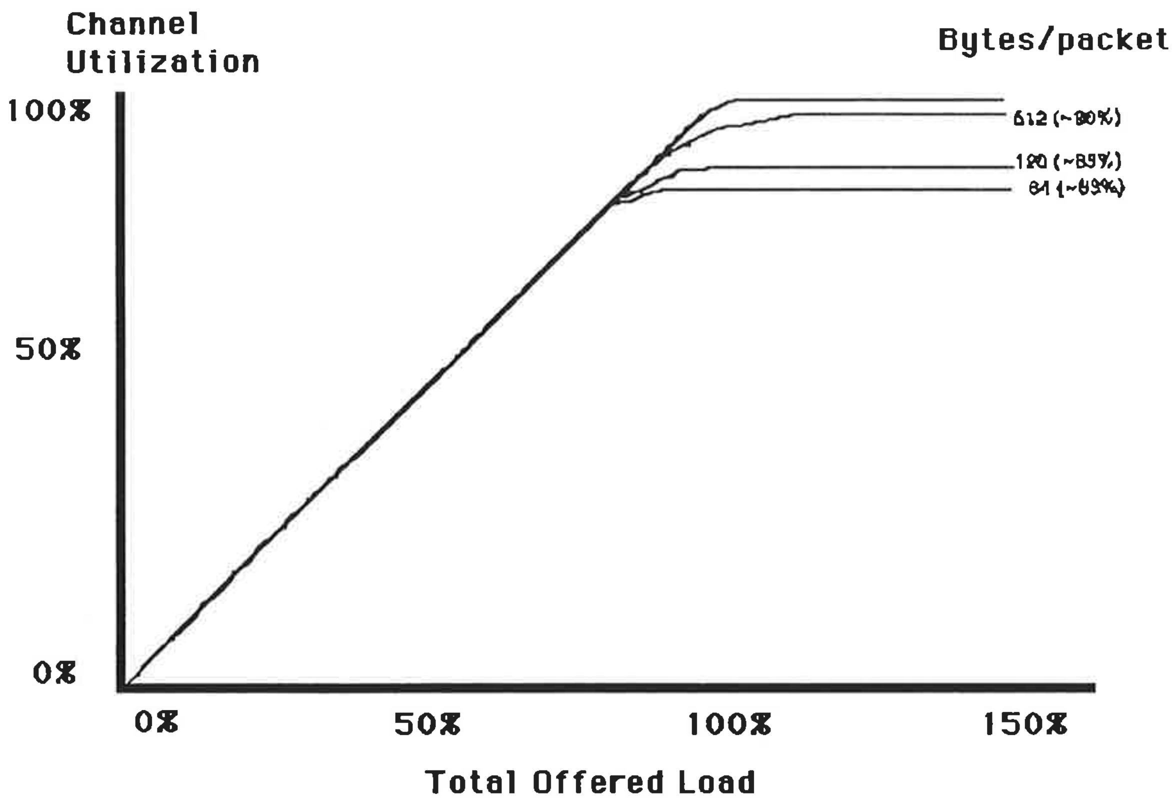
Profile

- 1-persistent CSMA with Collision Detect
- Collision detected within 64 byte (512 bit) times
- Collision Detect reduces wasted bandwidth when collision occurs - transmission aborted
- 1-persistent protocols not practical for heavily loaded channels without collision detect

Algorithm:

Sense the channel before transmitting.
If idle, transmit
If busy, wait till transmission is complete, then transmit with probability 1
If collision detected, do exponential backoff and repeat entire algorithm

Measured Performance of Ethernet



Measured Performance of Ethernet

Source: Measured Performance of an Ethernet Local Network, John Shoch and Jon A Hupp

Pros and Cons
(non-persistent CSMA)

Benefits
- Distributed control
- Algorithm run independently at each node
- Simple
- Extensive analytical and simulation work available
- Stable over loads well in excess of channel capacity

Cons
- Degrades in the presence of hidden nodes, Aloha in limiting case
- Throughput rises slowly at high load
  If offered load = channel capacity, throughput = ~50%
- Delay increases with load

Areas for study
- Generalized Busy Tone algorithm to reduce hidden node degradation[4]

Suitability to our application and consequent overall system characteristics deferred to a separate submission.

[4] Busy Tone is a contentious algorithm. While this author does not personally favour it, other IEEE 802.11 members may have supporting arguments.