SMAC™ – Applied as a New Gigabit Ethernet Protocol

A White Paper from SyncAccess Inc.

by

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ABSTRACT

The Ethernet CSMA/CD protocol has served 10 Mbps and 100 Mbps network users for several years and will continue to do so. But when advanced gigabit networks begin to apply CSMA/CD, severe system limitations become apparent. These limitations include a maximum hub diameter of 200m, poor (30 percent) transmission efficiency, and uncontrollable data latency. Surprisingly, these limitations are not due to the high-speed transmission rate or the transmission media, but to the actual CSMA/CD protocol itself. This paper explains why CSMA/CD cannot function at gigabit speeds. It further introduces a patented, alternative protocol: SMAC™ (synchronous medium access control). The SMAC protocol operates at near 100-percent efficiency at any speed. SMAC technology is fully compatible with CSMA/CD; it can be retrofitted with legacy networks and has a cost point comparable to Gigabit Ethernets.

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INTRODUCTION

Although there have been exponential increases in Ethernet speeds – as high as one gigabit per second and beyond – the reality is that most high-speed Ethernets cannot operate anywhere near their potential.

Why? Because Ethernets manage network traffic based on a 25-year-old protocol: CSMA/CD (carrier sense multiple access with collision detection). CSMA/CD is designed to manage information-packet collisions on the network. In such a collision-managed environment, high-speed networks only enable collisions to happen faster – especially when there are many users on the network.

These collisions delay transmissions and generate additional network traffic in the form of collision-detection signals and subsequent repeat attempts to send packets to their destinations. Using CSMA/CD to manage traffic on a busy network can reduce network efficiency to as little as 24 percent of its rated potential.

Although the CSMA/CD protocol has been exhaustively studied and improved upon over the years, it still operates on the assumption that collisions are inevitable.

As long as it is assumed there will be collisions, there will be collisions.

What if, however, it is assumed there will be no collisions? What if it is assumed there could be a protocol that precisely synchronized all data packets so that they would race to their destinations at maximum network speed in a "collision-less" environment?

There is such a protocol: synchronous medium access control (U.S. Patent 4,811,365). The SMAC protocol was invented by Phillip Edward Manno, technical director of SyncAcess Inc. of Sacramento, Calif.

The SMAC technology transcends collision-management with traffic-synchronization to enable both switched and non-switched Gigabit Ethernets to operate at near 100 percent efficiency. The protocol is designed to replace, overlay, or co-exist with CSMA/CD in all Ethernet networks in every transmission medium and on every computer platform.

Furthermore, SMAC technology offers features that will make Gigabit Ethernets more competitive – and compatible – with ATM (asynchronous transfer mode), SONET (synchronous optical network), Fibre Channel, and FDDI (fiber distributed data interface) technologies. For example, the SMAC protocol supports resource reservation setup protocol (RSVP) and qualities of service (QoS) for real-time video-audio-data transmission. Gigabit Ethernets cannot guarantee RSVP or QoS.

In cooperation with Altera Corrp. of San Jose, Calif, SyncAccess is targeting original equipment manufacturers in three specific markets:

- The global public network infrastructure for data and voice communications
- The Internet infrastructure that supports the World Wide Web
- Corporate wide area networks.

CSMA/CD - THE DOMINANT PARADIGM

In the beginning, there was the luminiferous ether - or at least, that's what scientists thought at the time. The ether was believed to be an "electronic wind" that carried radio transmissions. When it was later proved that the ether doesn't exist, modern technology immediately filled the vacuum with electromagnetic theory.

That was not the end of ether, however. Robert Metcalfe, Ph.D. – Father of Ethernet and founder of 3Com Corp. – recycled it. As he explained in a 1994 column for *Info World*:

> Ethernet got its name in a memo I wrote at the Xerox Palo Alto Research Center on May 22, 1973. Until then, I had been calling our proposed multi-megabit LAN the Alto Aloha Network. It was to connect experimental personal computers called Altos. And it used randomized retransmission ideas from the University of Hawaii's Aloha System packet radio network circa 970.
>
> The word ether came from *luminiferous ether* – the omnipresent passive medium once theorized to carry electromagnetic waves through space, in particular, light from the Sun to the Earth. Around the time of Einstein's Theory of Relativity, the light-bearing ether was proven not to exist. So, looking to name our LAN's omnipresent passive medium, then a coaxial cable, which would propagate electromagnetic waves, namely data packets, I chose to recycle ether.
>
> Hence, Ethernet.

And hence, history.

A Patented Success

The word "Ethernet" does not appear anywhere in the text of U.S. Patent 4,063,220, issued December 13, 1977. Nevertheless, more than 80 percent of the computer networks in the world now operate as Ethernets. This phenomenon is largely due to the success of 3Com Corp., which Metcalfe founded in his Palo Alto, Calif., apartment in 1979.

When Metcalfe and his colleagues (David Boggs, Charles Thacker and Butler Lampson) first invented Ethernet in 1973, their modest goal (relatively speaking) was to achieve a network speed of 10 million bits per second (Mbps).

It wasn't until 1985, however, that the Institute of Electrical and Electronics Engineers put its imprimatur on the 802.3 specifications for 10 Mbps Ethernets.

It took another 10 years for scientists and engineers to figure out – and agree on – how to make Ethernet networks run 10 times faster. In 1995, the IEEE set the 802.3u standards for 100 Mbps "Fast Ethernets."

It only took the IEEE three years to approve yet another tenfold speed increase to 1,000 Mbps – one gigabit – under the 802.3z specifications. The era of Gigablt Ethernets had arrived – well, mostly.

In 1998, the IEEE approved the standards for fiber-optic and coaxial cables for Gigabit Ethernet networks. The institute, however, held off on certifying the 802.3ab gigabit specs for unshielded twisted-pair (UTP) copper wire. The IEEE scheduled approval of standards for l000BaseT lines for March 1999.

Category 5 UTP wire is the installed base of a vast number of existing computer networks. The cost of rewiring those networks could be prohibitive. Thus, it is extremely important that Gigabit Ethernets be compatible with legacy 100Base *and* 10Base networks as well as the operating systems and application software used on those nets.

Non-Switched and Switched Networks

A traditional 10Base or 100Base network can be loosely termed a "non-switched" network, because it incorporates a shared, "half-duplex" path where only one node can transmit at any given time. When many nodes attempt to transmit, the probability of packet collisions increases. To evade the degradation in performance caused by packet collisions, the network must be segmented. One segmentation technique is to replace a I0/100BaseT or coax cable hub with a central hub-switching matrix. This is very expensive.

By having the segmented, half-duplex subsystems transmit independently, and then combining the multiple transmissions in a switching matrix, the various subsystems can communicate with each other with a reduced probability of collisions. This "collision evasive" system, however, is quite expensive, complex and requires elaborate software control. Even then, CSMA/CD collision switches employ a methodology that merely attempts to compensate for the shortcomings of CSMA/CD at high-speeds.

In contrast, because the SMAC design is a "collision-less" protocol, it can easily be deployed at gigabit bandwidths on a non-switched network. And when SMAC technology is applied in a switched environment, the switch matrix becomes low-cost, elegantly simple, and easy to control with a user-friendly interface.

CSMA/CD Dissected

In order to understand why SMAC technology is superior to CSMA/CD, it is necessary to understand CSMA/CD.

Carrier sense multiple access with collision detection is a MAC – medium access control – protocol. The function of a MAC is to enable nodes on the Ethernet to transmit information on a shared path without undue interference from other nodes.

In simpler terms, a "node" is a computer or some other device attached to the network, such as a printer. A "shared path" is any transmission medium (for example, coaxial cable, 100BaseT copper wire, or fiber-optic strand) that carries information from node to node. Information is transmitted in the medium as discrete framed data packets.

As a baseband medium, Ethernet can only transmit one packet at a time. The job of the CSMA/CD MAC on each node is to delay sending its data packet until it senses that the medium is clear of any other transmissions. Once the MAC perceives the line is clear, it transmits its data.

In the split-millisecond world of high-speed networking, however, a line can look clear to multiple nodes at the same time. Inevitably, some of the nodes will transmit simultaneously. And when that happens, data packets collide and the information is lost.

When a CSMA/CD MAC detects a collision, it backs off a certain increment of time before attempting to retransmit the lost data. The MAC generates the "backoff" time using pseudo-random numbers. Thus, each of the nodes involved in a collision will wait a different length of time to retransmit so they won't collide again.

Each time there is another collision, the MAC backs off a little longer until the data eventually gets through.

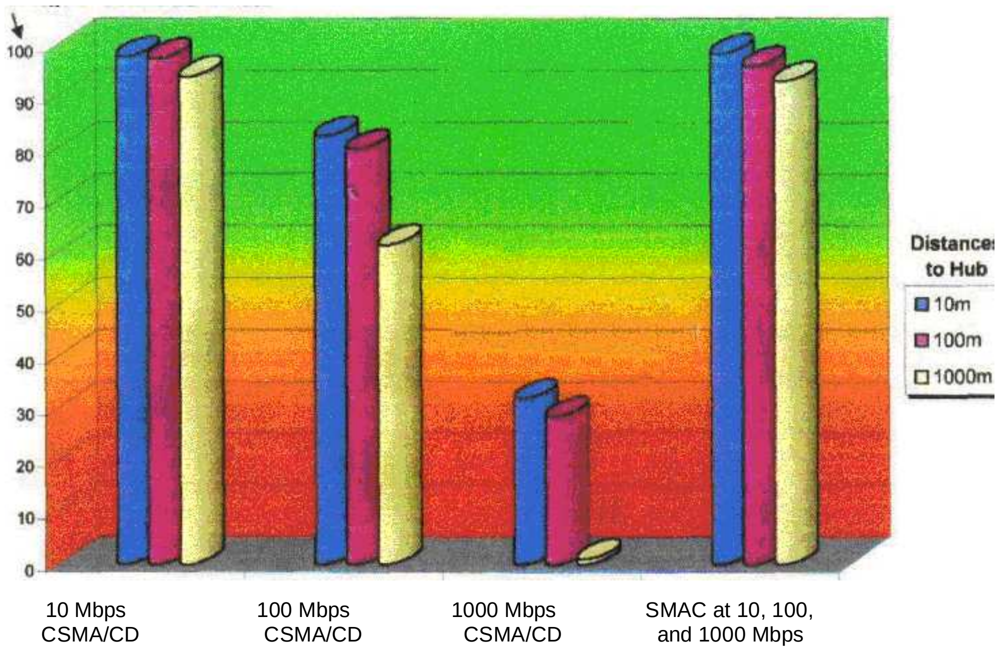
Putting CSMA/CD in Its Place

The CSMA/CD MAC protocol exists in most networked computers on an Ethernet NIC (network interface card). The protocol is implemented by semiconductors and software resident on the card. Its operation is so deeply embedded within the network layers that its operation is completely transparent to the user.

Although installing an Ethernet NIC into a computer is quite simple, the implementation of the CSMA/CD MAC protocol on that NIC is extremely complex. It is so complex, in fact, that there have been few challengers to its supremacy over the past 25 years. IBM's "token ring" MAC has carved out a niche in the market. And FDDI uses a variation of the token ring MAC. Nevertheless, the consensus is that more than 80 percent of the world's computer networks use the Ethernet CSMA/CD MAC.

CHART A

Percentage of Usable Bandwidth – CSMA/CD vs. SMAC



4096 bits per frame with 200 – 300 nodes

Although this is an impressive market share, CSMA/CD – no matter how much it's been tweaked and improved over the years – still has its one fatal flaw: collisions. As shown in Chart A,CSMA/CD is not cost-effective or practical on gigabit speed networks for the following reasons:

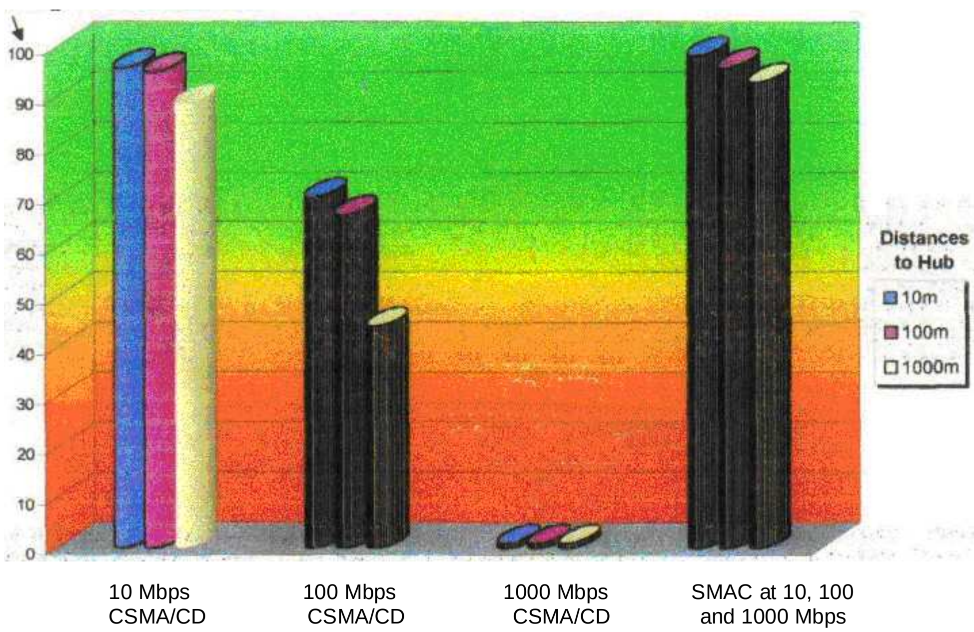
- **Data latency** – Because CSMA/CD is, quite literally, a hit-or-miss protocol, it is impossible to guarantee when and how much data will be transmitted. This makes it practically impossible to distribute real-time priority data packets. Real-time priority processes include financial transactions and broadcast-quality videoconferencing.
- **Quality of services** – The potential speed of a Gigabit Ethernet becomes irrelevant if it can't deliver consistent throughput – which it can't. The CSMA/CD paradigm puts Ethernets at an extreme disadvantage, at any speed, in competing with technologies such as ATM, SONET, and Fibre Channel.
- **Circuit-switching** – With circuit-switching, network managers can build large networks in which various data packets may be intelligently switched between Ethernet segments. CSMA/CD places a difficult burden on the network manager because of its random, unsynchronized nature. The difficulty lies in how to determine what circuit-switching assignments would be optimal.
- **Packet size** – According to the Gigabit Ethernet Alliance, Gigabit Ethernet networks require data frames to be of static size, regardless of the amount of information in the frame. The SMAC protocol can transmit frames of variable

sizes. A frame brackets a data packet with the destination address and other routing and error-checking codes.

Picture a CSMA/CD frame as a railroad boxcar. The amount of data is the freight. Empty, half-loaded, or chock-full, each boxcar takes up the same amount of space and time on the track. The SMAC protocol is more efficient because it fits the frame to the size of the data packet - no wasted time or space.

CHART B

Percentage of Usable Bandwidth – CSMA/CD vs. SMAC



2048 bits per data frame with 200 – 300 nodes

The reason why packet size cannot go lower than the 802.3z specifications is illustrated in Chart B. Quite literally, Gigabit Ethernets can't go the distance.

SMAC - THE NEW DOMINANT PARADIGM

A popular T-shirt in the Silicon Valley reads: "Subvert the Dominant Paradigm."

There is no argument that CSMA/CD is the dominant paradigm in computer networking at the medium access control level. It has reigned supreme for almost 25 years.

But CSMA/CD has not been able to keep up with the phenomenal growth – and change – in network speeds and bandwidth. Indeed, as shown, CSMA/CD is proving to be more of a liability than an asset to Gigabit Ethernet networks.

SMAC technology doesn't fix CSMA/CD. It replaces it. Instead of being a better protocol for managing information-packet collisions, The SMAC protocol so precisely synchronizes packet traffic that there are no collisions.

Synchronicity – Improving on a Good Thing

CSMA/CD is a reactive protocol, reacting to packet collisions. SMAC is a proactive protocol, preventing packet collisions.

SMAC is not the next-generation CSMA/CD. If anything, the SMAC protocol is the next generation of TDMA (time division multiple access) – a protocol used in satellite communications. TDMA is also used in GSM (global system for mobile communications) digital cellular systems.

Both the TDMA and SMAC protocols employ synchronous transmission management to allow multiple users to access a baseband channel simultaneously without interfering with each other.

SMAC technology, however, uses a more precise phase-synchronization algorithm to permit closer spacing of packet frames and thereby eliminates the wasted buffer time TDMA needs to prevent packet collisions.

Technically Speaking

According to U.S. Patent 4,811,365, SMAC is a protocol *"... wherein a plurality of nodes transmit over a common path on a time-sharing basis via a central hub."*

What happens is that one of the nodes on the network transmits a repeating, pre-established, pseudo-random, digital sequence at a pre-established bit rate. Once this sequence is established, this "reference node" begins to omit a portion of the sequence.

Another node wishing to transmit in the shared medium synchronizes itself with the omitted portion of the sequence. Precise synchronization is achieved by adjusting the bit rate, phasing, framing, and sequence portion. Once these nodes are "in sync," both nodes can transmit without interfering with each other.

As described in the patent: *"Since the slave nodes are in precise synchronization with the reference node, and the length of each node's transmission is exact and pre-established, each node can precisely calculate the time at which to begin its transmission without need for delay between transmissions or the danger of overlap."*

Shooting Silver Bullets

SMAC technology has an arsenal of "silver bullets" to rescue Gigabit Ethernet from obsolescence. The SMAC protocol:

- Can easily be applied over existing Ethernet environments and standards, including legacy systems.
- Is both compatible – and competitive – with Fibre Channel, SONET, ATM, and TDMA, among others.
- Is medium independent.
- Is platform independent.

- Is scaleable as your network grows and interconnects.
- Operates in both switched and non-switched environments.
- Has the same implementation cost point as upgrading to a CSMA/CD-dependent Gigabit Ethernet network.
- Does not suffer bandwidth loss over distance as network speeds increase. (See charts A and B.)
- Gives network designers and administrators more flexibility and simplicity (no data collisions to detect or manage).
- Offers built-in network management and diagnostics tools.
- Supports RSVP and QoS capabilities in the following ways:
    - Fixed data latency for near-real-time transactions
    - Encryption for secure e-commerce
    - Low-latency-mode data transmission
    - Dynamic bandwidth assignment
    - Variable frame sizes
    - Simple circuit-switching
    - Broadcast-quality multimedia transmission.

SYNCACCESS PRESENTS SMAC™

There is no better way to sell a product than to demonstrate it.

Therefore, Sync Access offers a reference design kit (RDK) in its primary product line. The RDK demonstrates semiconductor-level solutions that will familiarize you and your clients with the patented, synchronous medium access control protocol.

The RDK features PCI plug-in boards that can be configured to communicate from 155 Mbps to 1.2 Gbps in a variety of network configurations. Network engineers and researchers can select Category 5 unshielded twisted-pair or fiber optic interfaces for OSI physical layer (PHY) data transport.

Additionally, the RDK features state-of-the-art cabling layouts using passive optical couplers, demonstrable internetworking, and a user-friendly network monitor and control interface. For more information, visit the SyncAccess Product Page at: *www.syncaccess.com/products.htm*.

Who We Are, and Why We Are

We at SyncAccess are active and innovative leaders in the communications and data-networking industries. Within these industries, we provide advanced communication solutions – independent of transmission media – that incorporate our unique, patented technologies.

Our digital-based solutions can greatly expand bandwidth, flexibility, and capabilities on intranets, the Internet – and the Next Generation Internet – by migrating public and private networking systems from imminent obsolescence to world-class preeminence.

It is our goal to offer these superior solutions as open intellectual property licenses – both as silicon-level components – and in concert with SyncAccess's expert design services and total customer support.

In addition to our flagship product SMAC, we are developing two supporting patents that will integrate the next generation SMAC protocol with state-of-the-art data cryptography and advanced error-correction components.

On Target

We are targeting our products at original equipment manufacturers that supply these three fast-growing market segments:

- The worldwide public network infrastructure for data and voice communications;
- The Internet and Next Generation infrastructure that supports the World Wide Web; and
- Corporate, government and academic wide-area-networks.

We will service the increasing demand for improvements in the global communications infrastructure. More specifically, we will support the need for greater capacity and improved performance in transmitting near-real-time voice, video, and data.

At the software level, SyncAccess will be heavily involved in the design and integration of new network equipment with public networks used by local and long distance telecommunications service providers. Additionally, we will be involved in programming the new specialized networks used by Internet service providers and virtual private networks (VPNs).

At the hardware level, we will use our experience and expertise in working with multiple transmission media – including the latest fiber optics. We specialize in SONET/SDH and ATM products.

The complexity of these new networks requires advanced semiconductor devices that will allow network equipment manufacturers design and develop their products faster and at a lower cost. That's why we are working with Altera Corp., a leader in the manufacture of PCI boards and programmable logic devices.

Industry standards for products and protocols are continually evolving. Our future success depends on our ability to grow with these emerging standards. The SMAC protocol is proof positive that SyncAccess can not only keep up, but we can lead the way.

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SyncAccess
Provider of Innovative Communication and Cryptographic Solutions
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PHILLIP MANNO – BIOGRAPHY

Phillip Manno lives in a world of acronyms – CSMA/CD, IEEE 802.3z, SONET, 1000 Mbps, UTP, FDDI, QoS, MAC, l0BaseT, TDMA, and so on. Phill's favorite acronym, however, is SMAC™. He likes it best because he invented it (U.S. Patent 4,811,365). SMAC stands for synchronous medium access control, and that means Phill Manno just might set the global standard for high-speed computer networking in the new millennium.

Phill graduated from California Polytechnic State University in San Luis Obispo with a degree in electronic engineering. Furthermore, he has studied digital communications networks at the post-graduate level at the Massachusetts Institute of Technology.

During his eclectic career, Phill has designed an encryption engine for the U.S. Federal Reserve Banking System, developed satellite telecommunications for the Wall Street Journal, and worked on top secret fiber-optics projects for the Department of Defense.

At the tender age of 48, Phill was told by employers he was "too old" for the fast-paced environment of high-tech research and development. So Phill started his own company, SyncAccess Inc., in Sacramento, California.

SyncAccess is now building a reference design kit to demonstrate that the SMAC networking protocol is far superior – and much faster – than the current state-of-the-art CSMA/CD Gigabit Ethernet technology. CSMA/CD (carrier sense multiple access with collision detection) manages data-packet collisions on Ethernet networks. SMAC technology doesn't manage collisions. It eliminates them.

What's more, the SMAC protocol can be retrofitted to operate on virtually every Ethernet network on the planet. The implications are awesome: More than 80 percent of the computer networks in the world are Ethernets.

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SMAC™ the Dominant Paradigm!

The supreme irony of the Ethernet is that the very protocol – CSMA/CD (carrier sense multiple access with collision detection) – that makes Ethernets the most popular networking product in the world is the very same reason Gigabit Ethernets will never reach their full potential.

SMAC™ – Synchronous Medium Access Control – from SyncAccess Inc. is the next generation protocol for 21st Century Gigabit Ethernets.

SMAC technology doesn't solve the packet-collision management problems of CSMA/CD. It eliminates them. The SMAC protocol moves video, audio, and real-time data at guaranteed maximum throughput in "collision-less" RSVP and QoS environments.

SMAC technology enables your installed-base Ethernet to perform seamlessly, transparently, and effortlessly with legacy databases and competitive new technologies such as ATM, SONET, and ADSL – at the same cost point.

CSMA/CD is the history of the Ethernet.

SMAC is the future of the Gigabit Ethernet.