ABSTRACT

For the past decade or so, aut
subsystem architectures have c
Human Machine Interface (HMI),
deck, an amplifier and a set of sp
customer demand for more e
increased, automotive entertainm
room for new features by allo
integration of analog audio and a
The new digital control can
subsystems via a low speed
embedded into the enter
components, allowing remote c
features. New features were typi
the entertainment subsystem
packaging functional modules.
modules are cellular telephone,
(CDJ), rear-seat entertainment,
Radio System (S-DARS) receiver
with its associated display and ha
block diagram of typical entertain
paper discusses alternatives to th
entertainment subsystem via low
and analog audio. Moreover, the c
to cover future multimedia and in
interconnects technologies.

INTRODUCTION

Recently, great achievements h
information, communication, en
safety and security products. Mo
Transport Systems (ITS) services,
art electronics, are appearing o
drivers process information, n
operate vehicles more safely and e

As a consequence, our cars will b
more with digital systems
exchanging information. Wheneve
to go towards a super-integration o
number of them will always be
locations of the car. A transport l

features by allowing for the vertical integration of analog audio and adding a digital control. Despite the digital nature of most of the new added modules and the introduction of Digital Signal Processor (DSP) within the mobile multimedia system, the vertical integration of audio and its transport remained analog.

The Current mobile architecture with its analog transport has the following limitations:

- Analog transport complicates the subsystem interconnects, decreases reliability, adds weight and cost. Two twisted pairs are required for cabin media, one twisted pair is required for voice module, one twisted pair is required for cellular phone module, one twisted pair is required for navigation module, 3-5 wires are required for low speed multiplex scheme and synchronization. Additionally, two more twisted pairs are required for an optional media player such as CDJ. In the case of rear seat entertainment, more wires or coaxial cables are required for video. The number of wires or coaxial cables required for video applications is proportional to the number of rear seat occupants. Moreover, these wires require wide connectors with more pins at the analog power amplifier's input connector.

- The module level expansion strategy and vertical integration of analog audio resulted in a closed architecture with limited expansion path. The number of pins available at the power amplifier's input connector bounded the expansion path. In addition, the new subsystem had a short life and is not compatible with the digital trending of future entertainment features such as digital audio, digital video, Digital Audio Broadcast (DAB) and next generation of compact disc technology, Digital Versatile Disc (DVD).

- The module level expansion strategy and vertical integration of analog audio resulted in costly subsystem architecture. Often, modules added to the subsystem exhibited wasteful redundant hardware resources in order to achieve compatibility with an analog architecture. An example of this hardware wastefulness is the addition of a digital-to-analog converter to the output of CDJ or CD player to achieve compatibility with analog integration and processing. Moreover, the hardware resources available for each module are for that modules' own use and can't be shared with other subsystem's modules. This will add cost to each module and will contribute to the overall cost of the subsystem.

Presently, the module level expansion strategy and vertical integration of analog audio has reached its upper integration limit for an HMI, AM-FM tuner, voice, cellular phone, CDJ, a media player, Steering Wheel Control (SWC), a Rear Integrated Control Panel (RICP) and navigation. The implementation of such a subsystem requires seven modules and a minimum of 31 wires. A saving of one module and four wires is possible if a media, HMI, tuner, and power amplifier is packaged in one module. However, a complicated heat dissipation

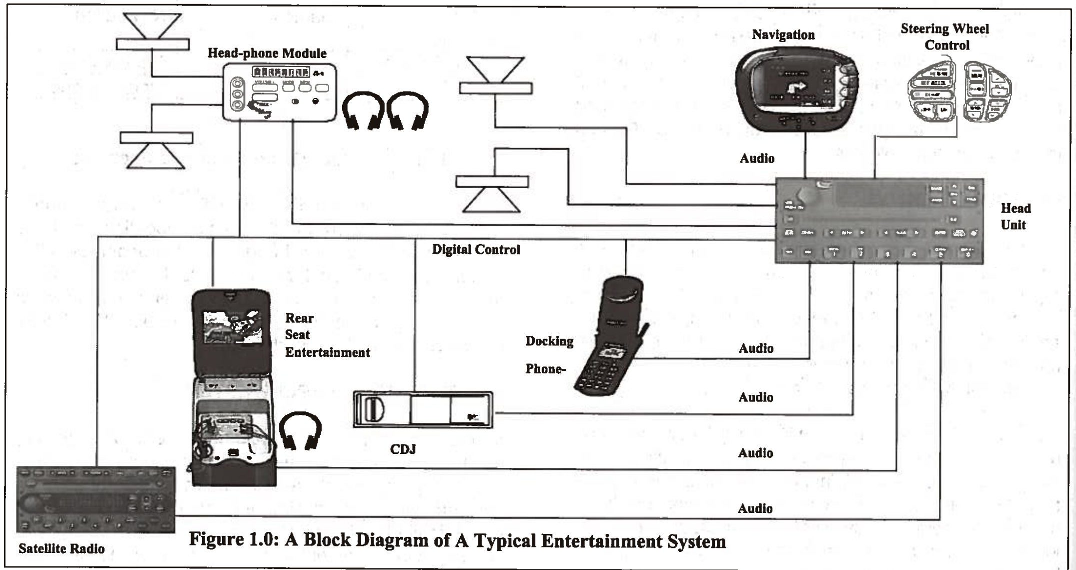

Figure 1.0: A Block Diagram of A Typical Entertainment System

and overall power management s
the success of such integration, a
performance.

REQUIREMENTS FOR NEW TRA

Vehicles are running out of the r
house new modules. Interconne
and costs are ever increasing.
discussion of both system and fu
for a new transport:

- Open Standard: the new trans
standard to ensure that all v
product manufacturers have
standard and to the market.

- Minimal Standard: the new tr
be extensible and capable c
technologies and different ph
impact on application software
to the protocol, such as is u
model of Open System Inter
shall be used.

- The new transport shall
multiplexing of data, control,
the same media. In addition, d
open system architecture; a r
anytime during the vehicle's lif
existing node's connector.
transport enables the natural t
from one ever increasing
another without exhibited
hardware resources such as D
and Analog-to-Digital (ADC) co

- Safety & Security: the new tra
environment into which devi
unplugged, and operated in a
which does not threaten the in
the devices that are being use
shall include suitable secu
involving the exchange of mo
information.

- Manufacturability: the new
devices and software shall
implement and integrate.
specifications and unambiguo
of manufacture helps to assur
the standard and contributes t
the manufactured items.

- Ease of Use: the addition or re
be easy enough for a consur
task with little or no expert ass

accommodate evolving technologies and new applications. A layered approach to the protocol is required to guarantee minimum impact on existing designs as new physical layers and new applications are developed.

- Security and Authentication Services: The new transport protocol shall provide security and authentication services for access to vehicle functions. It is anticipated that additional services will require additional security measures to accommodate applications or transactions that require billing, authentication, confidentiality, confirmation, non-repudiation, etc.

- Bit Error Rate: the bit error rate shall be less than 1 x 10^{-9}. Applications requiring better than this shall be able to implement appropriate measures at higher layers of the protocol.

- Time-Critical Delivery of Packets- Deterministic Latency: Some applications may require that messages be transmitted within a given time period. The new transport shall be deterministic and it shall be possible to determine the maximum latency for any message in a given system configuration

- Private Message Service: Equipment manufacturers wish to be able to develop applications that span their own suite of products and provide competitive functions and features not achievable when products from different manufacturers are interconnected. The new transport protocol shall support the implementation of private messages that will allow such applications to be developed.

- Power Loading: the new transport gateway shall make power available for all devices connected to the new transport system. The total operating current drain of all devices connected to the new transport shall not exceed the capacity of the gateway unless power is routed directly to the device from another source or the device is self-powered (e.g., internal batteries).

- Internetworking: it is anticipated that wireless access to and from the Internet will be required for many devices attached to the new transport system. The new protocol shall not preclude the future implementation of internetworking services across multiple gateways or bridges between the new transport and other subnets such as Intelligent Transportation Data Bus (IDB).

- Explicit Device Addressability: it shall be possible to send a message from a device to a specific other device. It shall be possible for the sender to determine and use the desired recipient's unique address to deliver this message and all other devices shall ignore it.

- Broadcast Messages: it shall be possible for an application to generate a broadcast message to all devices connected to the new transport without having to address each one explicitly. A broadcast message may or may not require acknowledgment or confirmation of delivery. For example, an application may require confirmation (acknowledgment) that at least one receiving device capable of acting on the message has received the message.

- Consumer-Friendly Device Connection (No Special Tools Required): in most cases, it shall be possible for a consumer to install new transport nodes with common hand tools. There will be cases where professional installation may be required, but this should be the exception, not the rule.

- Wake/Sleep: any node shall have the ability to wake up the new transport system or put it to sleep. It shall be possible to wake up the nodes by sending a wake-up message, such as a pager. It shall be possible to put any node and all connected devices back to sleep with a sleep message. Absence of message traffic on the new transport for more than 30 minutes shall cause the new transport and all attached devices to go to sleep.

- Priority Sensitive Flow (Isochronous): consumer electronics devices such as video games, DVD and MP3 players, Dolby AC-3 audio components, etc., may require support for high speed isochronous data communications (i.e., data packets delivered at a guaranteed rate in a guaranteed order).

- Data Types: The new transport protocol shall allow any data type (ASCII, binary, bulk, etc.) to be transmitted in a message without need for any special escape characters or other similar artifacts added by the application.

- Fair Access to the new transport system: no single device shall be allowed to monopolize the new transport system.

- Message Priority Flagging: the new transport protocol shall provide a means to specify that the current message is a high or normal priority message. The protocol simply provides a mechanism to identify the message as a high priority message. It is up to the device manufacturer to determine whether support is provided and up to the application software to determine what action is to be taken when a high priority message is received or presented for transmission.

- Confirmation of Message D
device sending a message to
able to explicitly request co
delivery of that message from

EXISTSING PROTOCOLS: ETHE
AND MOST

Fast Ethernet

Ethernet is a term commonly use
of network implementations that
technology. Some early variet
10Base-2 and 10Base-5 which a
and 'thick net' respectively. All n
tap into a single cable. A late
10Base-T, introduces the concept
All nodes are connected directly
which simplifies cabling and
electrical signals.

A newer version of Ethernet,
operates at 10 times the speed o
per second. It has the same star
and comes in a few different ver
TX, 100Base-FX, and 100Bas
between these versions is the p
electrical for TX and T4, and optic
Fast Ethernet will refer to the
100Base-TX.

Ethernet Topology

Thick net Ethernet uses a single c
the network. Each node in the
cable through what is called a T
environment, this cable could b
ceiling with taps dropping into e
well except it is difficult to add ne
and signal quality is sometimes dif

A Fast Ethernet uses a central re
directly to each node. This star
signal quality on the transmis
computer and the repeater to b
provides a relatively simple mea
repeater has a number of ports
computer on the network. To ad
wire is run from a free port on th
computer. If there are no free p
hub (or switch) can be connecte
expand the network to virtually any

Ethernet Physical Layer

operates just like the coaxial cable in thick Ethernet. If two computers try to send messages at the same time, the messages collide.

An Ethernet switch divides the network into many collision domains. Each port on a switch is a different collision domain. For example, if one computer is connected to a port on an Ethernet switch, the collision domain consists of two nodes; the computer and the switch. If a port on a repeater is connected to a port on a switch, the collision domain consists of the switch and all computers connected to the repeater.

The switch has intelligence which learns the addresses of the computers connected to each port. When a message is received at one port, the destination address is determined and the message is sent out the appropriate port. Switches are typically much more efficient than repeaters. However, they cost more.

Ethernet Communication Mechanism

Information in Ethernet networks is communicated in packets. Each packet consists of a header, usable data and a checksum. The header contains information such as source and destination address, the length of usable data and possibly information about the message type. The checksum is a code sent at the end of the message so that the receiving node can determine if the packet was corrupted during transmission.

Since the header and checksum are only used to send the packet safely from the transmitting node to the receiving node, it is considered network overhead. It is not information usable by the application. In Fast Ethernet, this consumes 18 bytes. If you include the arbitration time, the total overhead is 38 bytes. In addition, the minimum usable data is 46 bytes per packet. Even if you only wish to send one byte, you still must send the 18-byte header, 46 bytes of data, and wait 20 bytes worth of time for the bus.

The efficiency of the network can be defined as the number of user data bytes per packet divided by the number of bytes in the packet plus the overhead of waiting for the bus. If only one byte of user data is sent per packet the efficiency is 1/(64+20) X 100% = 1.2%. Since the maximum user data per packet is 1500 bytes in 100BaseT, the theoretic maximum efficiency is 1500/(1518+20) X 100% = 97.5%.

The maximum efficiency is never achieved since many collisions will occur if there is a lot of activity on the bus. The effect on efficiency is difficult to predict.

Ethernet Audio Example

particular Wav file from the server can be played on the sound card in the following way. The client software on the PC manages a FIFO (First-In First-Out) which continually outputs audio data to the sound card. When the FIFO gets close to being empty, the client sends a message to the server to send more data. The server sends another packet to the client to fill the FIFO up again. As long as the server sends the new packet before the FIFO empties, audio can be heard. If the server responds slowly or the network is very busy, the packet may not arrive in time, the FIFO will empty and sounds will momentarily stop. This is unacceptable for most audio applications.

There is a trade off between FIFO size, the frequency of requests for more data and packet size. Since the large packets are more efficient than small packets (% overhead from header, etc), let's assume we will use the largest packet size; 1500 bytes of user data. If the audio sample rate is 48 kHz, and the audio is 16 bits/sample stereo, then we need an average of 192K bytes/second or 128 packets/sec. The overhead for the header, checksum and the required idle between packets is 38 bytes. Since the client software on the PC with the sound card must inform the server when the FIFO is nearly empty, there are another 84 bytes of overhead to send this message to the server.

The minimum total bandwidth required for one audio channel is:

1500 + 38 + 84 = 1622 bytes/packet

1622 bytes/packet * 128 packets/sec = 207616 bytes/sec

207616 bytes/sec * 8 Bits/bytes = 1.66 Mbit/sec

Since the packet size in this example is the largest allowed by Fast Ethernet, the network overhead is small compared to the audio data throughput. The disadvantage of the large packet size is the buffer size requirement in the Client. It must be 1500 bytes deep plus more for handshaking. If the extra depth is not large enough for the network to guarantee another packet will arrive prior to the buffer emptying, a loss of audio quality may occur. If the buffer empties, the audio stops. In a Fast Ethernet, it is impossible to guarantee any bandwidth. If the network has lots of traffic, you may not even be able to get the 1.66 Mbit/sec average throughput that is required. More commonly, at times of high traffic the buffer may empty no matter how large it may be.

IEEE 1394

The IEEE 1394 specification is a hardware specification that defines the serial bus architecture that Apple computer initially named FireWire. It defines serial bus specific extensions to the Control and Status Register

(CSR) Architecture for Microcom
adopted as ISO/IEC 13213 (ANSI/

This architecture defines a set of
node architecture, address space
types, Control and Status Register
ROM format and content,
mechanism to all nodes and inte
nodes. IEEE 1394 specifies how
serial bus can talk to each other, b
protocols used to communicate be

IEEE 1394 is similar to Fast Etherr
is always communicated between
multiple nodes try to send packets
must arbitrate for the bus. The inf
headers, the packet sizes and the
different. However, the fundame
similar.

The most significant feature that
(which Fast Ethernet does not) is
for real time applications. The
allocated isochronous bandwidth
data to be communicated in packe
intervals. This is an improvemen
However, it will be shown that
limitations.

The raw bit rate for IEEE 1394 is d
between approximately 100, 20
Work is currently being done on an
as well. Silicon is currently being
both 100 and 200 Mbit. However,
are now at 100 Mbit/sec which is
the large installed base of 100Bas
currently under development as we

IEEE 1394 Physical Layer

The physical layer for IEEE 1394
twisted pair wire for signals and tw
ground connected between each
of twisted pairs is called data a
strobe. When one node begins to s
Nonreturn-to-Zero (NRZ) data o
transitions the strobe line only be
or 0's. Both sets of twisted pairs a
node sends and receives data on t
When neither node is sending data
held in a high impedance state.

In contrast, the physical layer for
of two sets of twisted pairs;
transmitting data and the other p
This approach makes recover
transmission line slightly more di

the same time, the transmitted data is corrupted, this condition is detected, and the nodes begin to arbitrate for the bus. Likewise, all nodes on an IEEE 1394 network have the same collision domain. Only one node can send a message at one time. If multiple nodes try to send messages at the same time, only one node will gain control of the bus.

In a Fast Ethernet, if a collision between two nodes occurs, both nodes will stop transmitting and wait a variable amount of time before another attempt. If they both happen to wait the same amount of time, another collision will occur. Mechanisms are built into the network to minimize the probability of nodes colliding more than once or twice.

An IEEE 1394 network operates differently. Nodes which are closer to the root node have a higher natural priority. When two nodes attempt to transmit at the same time, the node with the higher priority wins arbitration and control of the bus. In order to prevent higher priority nodes from monopolizing the bus a fairness interval is defined. During a fairness interval, all nodes are given the opportunity to send one message.

Unlike Fast Ethernet the arbitration mechanism in IEEE 1394 is deterministic. There is zero probability that nodes will collide many times before successfully sending a message. This is important for the delivery of real time data since any unpredicted delay, no matter how unlikely, may cause buffers to overflow or underflow.
The arbitration process in IEEE 1394 consists of bus request/grant handshaking between child and parent nodes. A parent node is defined as the node on a 1394 cable which is closer to the root. The node which is further from the root, is called the child. If a child and a parent both request the bus at the same time, the parent will block the child's request and send its request to its parent. The request continues down the tree until it reaches the root node. The root node issues a bus grant which travels back up the tree to the node requesting control of the bus. Once a node receives a bus grant, it can begin sending a message.

The time that it takes to arbitrate for the bus depends on the size of the network. A bus request from a node at the end of a number of branches must propagate down the tree to the root and back up the tree to the requesting node. Information must be sent down all other branches to prevent any other node from driving the bus (through a bus request), until the granted message is sent. The total arbitration delay for a network with N hops (from parent to child or child to parent) between the furthest two nodes, is about N x 80ns in a 100 Mbit IEEE 1394 network.

While Ethernet treats all packet data the same, IEEE 1394 provides different types of packets. The primary packet types are asynchronous and isochronous. Asynchronous packets are functionally equivalent to Ethernet packets. Isochronous packets are only available in IEEE 1394, and provide guaranteed bandwidth to time critical applications.

IEEE 1394 Asynchronous Packets

An asynchronous packet consists of a header, a header checksum, user data and a user data checksum. The header contains information such as source address, destination address, message length, message type, etc. The size of the header and the checksums is typically 24 bytes long. The user data can be up to 512 bytes long in a 1394 network operating at 100 Mbit/sec.

When a particular node receives a message, an acknowledgement signal is automatically sent back to the sending node. If the sending node does not receive an acknowledgement signal within a specified time, it will try to re-send it a specified number of times.

The total time required for sending a minimum size message consists of the arbitration time, the time to send the packet, the time to wait for an acknowledgement, the time for the acknowledgement message and a sub-action gap time. The sub-action gap time is the time required by a node to wait after the bus is idle before it can issue a bus request. The sub-action gap time is required to ensure that no node will issue a bus request before the previous acknowledgement is received.

The total time for a one byte message in a large network (16 hops) running at 100 Mbit is about 1.4 µsec for arbitration, 2.2 µsec to send the message (28 bytes * 8 bits/byte * 10ns), and 5.6 µsec for acknowledge and sub-action gap. The total time is about 9.2 µsec. This means the efficiency is about 80 ns / 9.2 µsec X 100% or 0.9%. The total time to send a maximum size message (512 bytes) is about 50 µ sec with an efficiency of about 85%.

IEEE 1394 Isochronous Packets

The most significant improvement of IEEE 1394 over Ethernet for real time audio, video and voice applications is 1394's isochronous channels which provide guaranteed bandwidth to applications. When an application is allocated an isochronous channel, it is guaranteed to be able to send isochronous packets at regular intervals to any other nodes in the network. Each node in the network has a counter which defines these regular intervals. The Isochronous Resource Manager sends a message periodically to synchronize the counters in all nodes.

The Isochronous Resource Mana
which is clocked by a local 24.57
up to 3072. When the count
Isochronous Resource Manager
broadcasts a message to all the
reset their local counters. T
synchronization message is 24.57

After the synchronization messa
been allocated isochronous ba
send their packets. After all iso
been sent, then nodes that
asynchronous packets are allow
between the 8 kHz sync messa
maximum time that can be alloca
is 100 µsec. This ensures tha
always be available for some asy

IEEE 1394 Audio Example

The concept of an isochronous
problem illustrated in the
communicating audio over Fast
that is allocated isochronous ban
be able to send a packet ever
described in the Fast Ethernet
due to congestion on the networ
audio data packets are guarantee
it is intended that handshakin
necessary. These are required
example since the server needs
in the PC with the sound card is

To send 16 bit stereo audio data
over an isochronous channel r
bytes per isochronous packet. Thi

48 kHz * 2 bytes/sample * 2 chan

192k bytes/sec / 8k packets/sec =

The header for an isochronous
bytes which specify the length of
bytes), the channel number, e
checksum for just the header. The
consumes another 4 bytes. In tota
header and checksum overhead
bytes.

Additional overhead comes in the
gap time between packets and
symbols. The gap time and s
consume a fixed time equivalent
transmit about 3 bytes in 100
arbitration time depends on the si
large network that has 16 node

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