M2G_Requirements

M2G

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1 Document contents

With the M2G protocol a high performance, very scalable and easy to implement multi media transport system for in car use shall be defined. Inspired by the MOST protocol (Media Oriented Systems Transport) (http://www.mostcooperation.com) but with many innovative improvements it shall be proved that with already existing technologies a far higher bandwidth for in car communication is possible.

This document contains the requirement analysis of the M2G project. Its goal is to analyse the history, judge the present and define the future.

Requirements are marked as follows:

Requirement: Example

Any OEM (car manufacturer) and Tier1 are welcome to participate in this project and to support my work. If you find mistakes in my documentation feel free to inform me.

2 M

2.1 Main principles

M is an optical or electrical ring topology. It uses bi-phase encoding for the 25 and DCA encoding for the 50 and 150 Mbps versions which are both DC free. On M there is always one master and up to 63 slaves. The master (m0) provides the ring sampling rate fs by generating empty frames every 1/fs. The following slave (s1) receives this frame recovers the bit and frame clock inserts its own data on the fly as well as extracts data from preceding nodes and forwards the modified incoming frame to the next slave (s2). This forwarding continues until the modified frame reaches the master (m0) again which copies the incoming data to the next frame generated.

M provides three major transfer types: Control messages, asynchronous packets and synchronous channels.

Control messages are small packets of data send from one node to one, several or all other nodes spread over several frames. They are protected by an CRC and retried by the most controller (INIC, intelligent network interface controller) when the transmission was disturbed or the destination node was not able to accept the message. For control messages only a small fraction (2 byte per frame for M25, 4 byte per frame for M50 and M150) of the entire bandwidth can be used and all nodes have to arbitrate against each other node before getting the access granted. The maximum length can be 32 bytes for M25 or up to 68 bytes for M50 and M150.

Asynchronous packets can have a length of 1 to 1024 bytes for M25 and 1 to 1500 bytes for M50 and 150. Like control messages they come from one node and can be addressed to one, several or all nodes. Their data content is CRC protected but not automatically retransmitted in case of transmission errors (like Ethernet UDP). Packets must share their available bandwidth with synchronous channels and can be user defined via the SBC setting from 16 to 60 bytes per frame. A typical value for SBC is 48 byte per frame for synchronous channels and 12 bytes for packets. Because of that packets must be split over several frames.

Synchronous channels are stream oriented byte transmission pipes which are in fact simply 1 to 60 bytes per frame forwarded from one node to the next. A sending node simply writes its audio samples into one frame after another and another node copies this byte to its audio sink which makes the signal audible. Synchronous channels share the available bandwidth with asynchronous packets.

Figure 2.1 : M25 frame structure

The secondary transfer types over M are isochronous streams and Ethernet tunnelling.

Isochronous streams on M are an interpretation of the data in synchronous channels. When a data source wants to transmit a block of isochronous data it first writes a block start delimiter to the synchronous channel followed by a block length and the payload it self. At the stream sink the node has to observe the synchronous channel all the time and scan for the start delimiter. When the node finds it, it just reads the block of data.

Ethernet tunnelling is done via asynchronous packets. To do this the max packet size was extended from 1024 to 1500 bytes per packet from M25 to M50. On M50 the NIC is able to handle automatic retransmissions of bad packets.

2.2 Characteristics of M

Good things on M:

- Deterministic bandwidth for messages, packets and channels.
- Proven for Audio, Video and Ethernet.
- Fast data propagation. Messages=16 frames, packets=1…256 frames, channels=1 frame.
- Automatic arbitration of messages and packets by priority and delay.
- Central resource (CRA) management in the master.
- Messages are protected by CRC and automatically retransmitted.
- Ring break diagnosis. Is this really important?
- Node, broadcast and groupcast addressing (groupcast buggy and not recommended!).
- DTCP officially supported and approved.
- Fs distribution for synchronous audio replay.
- Well specified and widely used function catalogue.
- Supports sleep and wake-up methods.
- Automatic node enumeration.

Bad things on M:

- Monopoly of M founders with secret protocol specification leads to many problems:
    - Technology advances relay on one single company (slow)
    - New technologies can not be reviewed by others (risk)
    - Availability of controllers from single source only (risk)
    - Protocol bugs are not solved but concealed
    - High price for INIC because of lack of competitors (costs)
    - Development tools are bad. (time to market)
    - Limited number of controller variants available (market acceptance, costs)
- Jitter propagation. In all three existing M versions the master generates the frame and bit clock for the entire ring. Every node has to recover a bit sampling clock from the data stream of the preceding node (not bad yet) and use this clock for its outbound data stream. Because the clock jitter for the last node in the ring is the sum the node jitters of all preceding nodes the PLL design a very critical task. Clock jitter is not only introduced by the controller but also by the optical components which make them expensive. A point-to-point clock transmission could solve this problem.
- Fix bandwidth distribution. The bandwidth for messages, packets and channels are fixed during run time. While during start up phases a high load of messages are required and no channels are active, during run time nearly

no messages and many channels are required. An automatically adjusted dynamic bandwidth distribution would improve things a lot.

- The bi-phase encoding of M25 requires a 50 MHz bit rate, which makes optical components more expensive. This problem was solved with the M50 and M150 DCA encoding.
- Maximum bandwidth of 150 Mbps.
- High price for optical components.
- No FPGA and ASIC versions of M controllers available; only INICs.
- Special interface (MediaLB) required for INIC access. To access an INIC150 a 300 Mbps bidirectional LVDS interface is required. Why not simply using the 300 Mbps interface for M2G?

3 Transport mechanisms

As multi media signifies several different mechanisms must be considered. The main multi media data types in cars are:

1. Audio
2. Video
3. DTCP (encrypted streams)
4. Navigation data
5. Ethernet / Internet
6. System control
7. Production programming data

3.1 Audio

Audio transmissions cars can have the following characteristics:

1. raw unencrypted or encrypted (e.g. DTCP)
2. stereo or mono
3. 8, 16 or 24 bit
4. sample rates of 44, 48 or 96 kHz
5. permanent stream or bursts of data

The first supported source of digital audio data was a CD player. A CD player reads a PCM code with a given clock rate from the CD and converts it to a binary encoded signal stream. CDs contain 16 bit stereo data with a sampling rate of 44.1 kHz.

DVD audio supports nearly any combination of the following parameters:

- 16, 20 or 24 bit
- 44.1, 48, 88.2, 96, 176.4, 192 kHz
- mono, stereo, surround

See [1] for details.

Requirement: Continuously streams of unprotected data with deterministic receiver latency shall be supported.

Requirement: Sample widths from 8 to 24 bit shall be supported.

Requirement: Sampling rates from 44.1 to 192 kHz shall be supported.

Hardly found DAT tapes are recorded with 48 kHz and 16 bit stereo.

S/PDIF is a transmission protocol like MOST and M2G. In fact MOST is a derivate of S/PDIF. It is intended to connect local digital audio devices like CD players to digital amplifiers or your DVD player to your surround sound decoder.

I²S is also a transmission protocol intended to connect digital audio chips on a PCB. It mainly supports stereo signals with an unspecified number of bits per sample.

Dolby Digital (5.3, 7.1) support sample rates from 48 to 192 kHz and 16 to 24 bit. It can consume up to several Mbps depending on the encoding and the dynamics of the audio signal.

Simple audio signals like cell phone rings or indicator clicks might be stored as short images inside the program memory of the ECU or in time generated by math functions. Because of the limited complexity of such signals sample rates from 16 to 48 kHz and with widths of 8 to 16 bit are sufficient.

All constant rate digital audio streams have in common that they are generated with a fixed sample rate, transmitted to the speaker and played back at the same or different sample rate. It is important that those samples are played at a constant rate otherwise audible distortions will occur. On M the source and sink of digital audio streams are directly coupled via the M frame rate. Either both use the M recovered clock as reference clock or the source or sink has to use a sample rate converter (see chapter 4 for details) to adjust the different sample rates. For an ease of use M2G shall provide means to distribute a common system reference clock.

Requirement: A common reference clock shall be distributed to all M2G nodes.

Requirement: The reference clock shall have such qualities that it can be used as an input for a PLL or DLL for clock multiplication.

Encrypted audio streams mostly use DTCP. See chapter 3.3 for details.

Another requirement for in car audio transmissions is the transmission delay or echo. Echo becomes audible for men if the time delay between two speakers exceeds 10 ms [11]. In a car this shall be the worst case delay between any two speakers.

Requirement: Limit the transmit delay all over the network to less than 10 ms.

3.2 Video

For video streams the most famous format is MPEG 4 because of DVDs. For copy protection data from DVDs must only be transferred from a source to a sink in an encrypted format. DTCP is the mostly used standard and is also used for M. See chapter 3.3 for details.

Other data formats like AVI or WMV are currently not present in cars and are therefore not analyzed here.

Unprotected video streams like pictures from driver assistance cameras can have many different formats. The simples would just be to transfer the raw data stream as a continuous bit stream or in a burst manner in blocks of data.

3.3 DTCP

With DTCP an industry standard for data stream encryption exists. It is used by M to distribute not only audio streams and is accredited by the music and video industry to transport commercial movies and sounds.

DTCP communication first exchanges keys between a source and a sink and then uses a block or burst wise data transfer for the stream. On M DTCP uses control messages for the key exchange and isochronous (block wise transfers over synchronous channels) for the encrypted stream. On M2G also a packet oriented transfer could be suitable.

Requirement: High bandwidth block transfer mechanisms with data protection shall be possible for DTCP transfers.

Requirement: A fast and reliable communication channel for DTCP key exchange shall be available.

3.4 Navigation data

The primer characteristic for Navigation data is reliability. If on navigation data chunks are lost or incorrectly transmitted the navigation system might crash. Therefore a protected and reliable communication channel with a bandwidth of up to 10 Mbps is required.

Requirement: A bandwidth of up to 10 Mbps over a reliable communication channel is required for navigation data transfer.

Navigation data is sent from a single source to a single sink and therefore needs no broadcast addressing.

Since navigation data is not very timing critical it does not add additional requirements to M2G.

3.5 Ethernet / Internet

Ethernet communication nearly always uses the higher layers of TCP and IP for transmission control and protection. TCP/IP adds a header and a checksum to the payload and transmits it to the sink. When the sink receives a packet it checks the payload against the checksum and either acknowledges (ack) or not acknowledges (nak) the packet to the source which has to retransmit the packet. So it uses a per packet handshake mechanism to assure the correct transmission. As with all hand shake mechanisms the bandwidth and latency strongly correlates with the speed of the turn around times for handshakes.

Requirement: Ethernet tunnelling requires a protected and packet oriented data transmission mechanism.

Requirement: At best use hardware protection mechanisms to boost the packet bandwidth without upper layer influences.

Requirement: For a high bandwidth on the packet channel an entangled packet acknowledgement mechanism could be desire full.

Ethernet packets have a maximum size of 1500 byte payload for 10, 100 and 1000 Mbps. 1 GE additionally supports jumbo packets with up to 9 kB. See [8] for details. To be fully compatible M2G shall provide mechanisms to split Ethernet packets from any length into smaller chunks for transmission.

Requirement: Provide means to split large packets into smaller chunks automatically.

When the full bandwidth of M2G which could be as high as several Gbps shall be used for Ethernet with a standard packet size of 1500 bytes per packet this leads to a very high number of packets per second. This might put a high load to the application CPU unless a DMA unit is used.

Requirement: Provide DMA aware interfaces to the packet channel.

TCP/IP packets support broadcasts.

Requirement: Provide protected broadcast capabilities to all nodes.

3.6 System control

To control the system a reliable messaging system must be provided. Low latencies provide fast reaction times.

Requirement: Provide a reliable message system.

Requirement: Provide a low latency message system.

4 Sample rate conversion

Sample rate conversion means to interpolate signal samples between two known samples. In audio systems an analogue signal is sampled at fixed frequency fs. If these samples are replayed with different fs the frequency of the original analogue signal is transformed in the same scale as the two different f_s. To transmit a signal without any alternations the sampling clock and the replay clock must match.

In the digital world also another problem occur when both f_s differ: Buffer underflow or overflow. Independent clock sources never match their frequency by 100.00%. Because of temperature, aging and other effects they will drift over time. A standard crystal has e.g. a precision of ±50 ppm which means that frequently samples must be dropped or inserted which could have a negative effect on the sound quality.

Continuous video streams are less affected by differing f_s because they do not change their information content (matrix of pixels) as audio waves do (frequencies). But they also suffer the buffer overflow and underflow problem which could cause buffer under runs which might cause hopping movies.

Compressed video streams are not affected by differing f_s because they use block transfers to fill up their input buffers, run the movie on the sinks frequency and request a new block of data whenever they need a buffer refill. This means that they use a regulation algorithm to keep their buffer full. Most video streams are compressed and encrypted streams.

Because sample rate conversion is a complex calculation it costs money. Therefore the best solution to avoid it would be to propagate the f_s over the network for raw streaming systems.

Requirement: Provide means to transmit source f_s to one or more sinks.

5 Vehicle usage

5.1 EMI

For the reduction of electro magnetic interferences M2G shall be prepared to use robust physical layer circuits such as Ethernet, CAN, PCIe or M. EMI means emissions and immissions.

Emissions may disturb other electronic systems and is mainly caused by strong EM field generated by the network communication. Such fields can be reduced by using

- Optical media (no e/m emissions)
- Spectrum spreading and data scrambling (spectral energy is spread over wide frequency range)
- Low radiation encoding (spectral energy is spread over wide frequency range)
- Differential electrical signalling (low levels + emission cancellation)
- Shielding
- Optimized signalling levels

External immissions may disturb M2G by manipulating data bits. Their effects can be reduced or corrected by the following means:

- Optical media (no effected by e/m fields)
- shielding
- twisted electrical wiring (cancellation of immissions)
- error detection and correction
- optimized signalling levels (high immunity)
- redundant data transmission

M. uses both optical and electrical wiring but optical transmissions seem to be more cost effective in cars.

Requirement: M2G shall support optical media.

Requirement: M2G shall support electrical media

Requirement: M2G shall support spread spectrum clocking

Requirement: M2G shall use data scrambling

Requirement: M2G shall use CRC error detection

Requirement: M2G shall support retransmission of faulty messages

5.2 Temperature

Components for a media bus in vehicles must be able to withstand lower and higher temperature levels than commercial bus systems. There are three major temperature ranges on the market: Commercial (0°C..70°C), industrial (-20°C..80°C) and automotive (-40°C..105°C). For M2G the automotive range must be the final target. For a first protocol evaluation the temperature range is secondary which allows using all available gigabit PHY technologies on the market and having a dedicated automotive PHY developed afterwards for read in car use.

Requirement: Mass production M2G components shall be automotive temperature rated.

Requirement: M2G evaluation can use any temperature rated components on the market.

5.3 Modularity/ Dynamic node change

Cars are manufactured in many variants with different features. This is especially to entertainment options true. Therefore it is important that M2G supports automatic ring configuration detection mechanisms where depending on the bus topology and node extension nodes might be omitted or available.

Requirement: Automatic detection methods for bus topology and node extensions shall be possible.

5.4 Number of nodes

M supports one to 64 nodes. For a car 16 nodes are a sufficient number of nodes if several surround sound, navigation and rear seat entertainment are considered. For busses, planes, trains or other use cases like building entertainment a far higher number of nodes (>50) are required but they are not in focus of this project.

Requirement: At least 16 nodes must be supported on M2G.

5.5 Power consumption /sleep

Power consumption in cars is a critical topic. Because all electric power must be generated from fuel and fuel becomes more and more expensive car manufacturers are forced to reduce any power waste. Additionally low standby currents are demanded to save battery power when the car is off. M uses an activity detection circuit inside the FOR which switches the ECU power on and off. Because M2G will be able to support many different physical interfaces there are different methods for sleep and wakeup detection and forwarding.
A current INIC25 consumes about 600 mW together with the FOT and FOR about 700 mW must be calculated. Lattice advertises their FPGAs with integrated SERDES to consume only 100 mW per SERDES @ 3.125 Gbps. Expecting about 3000 LUTs

Requirement: M2G shall provide means to bring the bus and all nodes into sleep mode and back to active mode.

Requirement: M2G shall be programmed in a power efficient way like low clock speeds, clock gating, low toggle rate idle patterns.

Requirement: M2G shall provide means to deactivate nodes entirely or partly if they are not required.

E.g. special wake up patterns or messages within the normal data stream could be used to wake or sleep single nodes explicitly. It could also be possible to have only the message circuit running and having the synchronous parts deactivated.

Requirement: M2G shall provide means to bypass a node.

5.6 Price sensitivity

Standard technologies and components; SERDES, LVDS

5.7 Scalability / Migration to new demands

5.8 Bus topology

Ring vs. three vs. string, mixed

5.9 FPGA and ASIC

BIST, Reset clock, external RAM, single port RAM

5.10 External interfaces

CPU, DTCP decoder, streaming fifo,

6 Debugging

6.1 BIST

6.2 Loopback

6.3 Bus error state detection

6.4 Bus read only mode (BROM)

7 Compatibility to M

8 Available technologies

9 Requirements summary

10 Links

[1]	http://en.wikipedia.org/wiki/DVD-Audio
[2]	http://en.wikipedia.org/wiki/PCM
[3]	http://en.wikipedia.org/wiki/Spdif http://www.epanorama.net/documents/audio/spdif.html
[4]	http://www.mostcooperation.com/home/index.html
[5]	http://en.wikipedia.org/wiki/I2S
[6]	Dolby Digital FAQ http://www.dolby.com/assets/pdf/tech_library/42_DDFAQ.pdf
[7]	http://www.dtcp.com/
[8]	Ethernet packet size http://sd.wareonearth.com/~phil/jumbo.html
[9]	Sample rate conversion http://ccrma-www.stanford.edu/~jos/resample/ http://focus.ti.com/docs/prod/folders/print/src4190.html
[10]	TSMC semiconductor technologies brochures http://www.tsmc.com/english/a_about/a05_literature/a0501_brochures.htm
[11]	http://www.sageinst.com/downloads/925/ecegwp1.pdf
[12]	http://en.wikipedia.org/wiki/Reduced_Gigabit_Media_Independent_Interface http://www.hp.com/rnd/pdfs/RGMIIv2_0_final_hp.pdf
[13]	Xilinx MOST IP core http://www.xilinx.com/products/ipcenter/DO-DI-MOST.htm

11 Abbreviations

PCM	Pulse Code Modulation, see [2] for details
DTCP	Digital Transmission Content Protection; see [7] for details
S/PDIF	Sony/Philips Digital Interconnect Format; see[3] for details
M, MOST	Media Oriented Systems Transport; see [4] for details
IIS, I²S	Inter IC Sound; see [5] for details
PCB	Printed Circuit Board
ECU	Electronic Control Unit; mainly in vehicles
kbps	Kilo bits per second
kBps	Kilo bytes per second
Mbps	Mega bits per second
MBps	Mega bytes per second
Gbps	Giga bits per second
GBps	Giga bytes per second
DLL	Digital locked loop; digital clock multiplier
PLL	Phase locked loop; analogue clock multiplier
ppm	Parts per million
RGMII	Reduced Gigabit Media Independent Interface; see [12] for details
FOR	Fibre optical receiver
FOT	Fibre optical transmitter
SERDES	SERializer/DESerializer
LUT	Look Up Table
LE	Logic Element

12 Document history

Version	Change
V1.0 dated 2008-06-01	Work begun