DEVELOPMENT OF AUTOMOTIVE ETHERNET FOR VEHICLE INFOTAINMENT SYSTEMS
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• Motivation for Ethernet in Infotainment

• InControl Touch Pro Infotainment System
  – BroadR-Reach® Physical Layer
  – Network Structure and Protocol Software

• Standardisation Bodies

• Future Standards

• Ethernet Future for Automotive
MOTIVATION FOR ETHERNET

• Infotainment features
  – Pace of development needs to align with consumer electronics
  – GENIVI type architecture supports this
  – Greater network bandwidth demands

• Vehicle systems becoming more integrated
  – ECU reduction, minimise power consumption and CO₂

• Desire for:
  – New and upgradable software based features, remote servicing and upgrades, car-2-X communication, abstraction of software from the hardware platform, **scalable network bandwidth**
CURRENT INFOTAINMENT ARCHITECTURE

- JLR Premium Infotainment System
  - MOST-25 Fibre Optic Ring Network, 25Mbit/s
- 25Mbit/s bandwidth shared between all nodes
• MOST-150 available, 150MBit/s Fibre Optic Ring Network

• 150Mbit/s shared between all nodes
  – Bandwidth constrained capability to transport different HD-Video streams to all zones of the vehicle, and Internet traffic, and vehicle data, and HMI…
  – Application software tied to the network technology
  – Historically, long development cycle
Jaguar Land Rover reveals InControl Touch Pro, its next generation infotainment and connected car technology in the all-new Jaguar XF.
• New “InControl Touch Pro” infotainment system developed by JLR
• Announced at the launch of the all-new Jaguar XF 2016MY
• Ethernet based – BroadR-Reach® 100Mbit physical layer
• Switched network
  – Each link 100Mbit/s full duplex
  – Add bandwidth where it is needed
  – Complete flexibility on configuration of each link
  – Fault tolerance
  – Upgrade to Gigabit Ethernet later where it is needed without major redesign
AUTOMOTIVE ETHERNET CHALLENGES

• “Just use Ethernet”
  – Not so simple…
  – Automotive places many new constraints

• Electromagnetic Compatibility (EMC) Corporate and Legal Requirements

• Quality and Robustness

• Environmental

• Cost

• Cables & Connectors

• Chipsets (Automotive Qualification)

• Driver Software
- JLR BroadR-Reach® development started early 2012
- Identified key requirements to be met by the physical layer
  - Infotainment’s requirements plus –
  - Quality, EMC, harnessing, manufacturing, service, hardware platform, vehicle development timing, core networks… all placing constraints
  - But - we can not allow the network to constrain the infotainment features
BROADR-REACH® OVERVIEW

- BroadR-Reach® designed to work over one Unshielded Twisted Pair Cable
- Standard Fast Ethernet (IEEE 802.3 100BASE-T) requires two Shielded Twisted Pair cables in a vehicle environment
BroadR-Reach® link performance can be described as a function:

\[ Y = \text{BroadR-Reach® link performance} \]

\[ Y = f(X_1, X_2, X_3, \ldots, X_n) \]

Where:

- **X1** = Link length
- **X2** = Individual wire length
- **X3** = Link symmetry
- **X4** = Cable distance from ground plane
- **X5** = Cable distance from other cables
- **X6** = Cable screening
- **X7** = Connector type
- **X8** = Connector symmetry
- **X9** = Connector Impedance
- **X10** = Distance to other connector pins
- **X11** = Link interconnects
- **X12** = Degradation (squash)
- **X13** = Degradation (torsion)
- **X14** = Degradation (tension)
- **X15** = Degradation (bending)
- **X16** = Degradation (ageing)
- **X17** = Link termination
- **X18** = Cable twisting
- **X19** = Cable twisting at connectors
- **X20** = Cable characteristic impedance
- **X21** = Link attenuation
- **X22** = EMC filter circuit
- **X23** = Common Mode Choke
- **X24** = Input voltages
- **X25** = Ground offsets
- **X26** = Phy configuration
- **Xn** = Phy input clock
Effect of each variable (Xi) on data integrity and EMC performance characterised through practical tests, at device level...
BROADR-REACH® TESTS

…and installed in a vehicle
Many variables can be fixed during the process of meeting other requirements, for example:

- Jacketed cable fixes the twist rate, and makes distance from ground plane and other cables insignificant
- Connector system with controlled assembly process eliminates concerns of link symmetry and untwisting at connectors
- Point-to-point links only for Ethernet, no splicing or topology concerns

In conclusion – there are many variables, but the challenge can be made simpler depending on the exact goals of the system in which BroadR-Reach® is used
**BROADR-REACH® DIAGNOSTICS**

- Physical layer link diagnostics - Open Circuit / Not connected
  - Handled by one end of each link in the BroadR-Reach® Phy
  - In our case in the Master Controller containing the Switch

- Link signal quality
  - Can be measured in the BroadR-Reach® Transceiver
  - Note that this applies only to data integrity, *not* EMC performance
  - EMC performance must be assured by design
• BroadR-Reach® specific software developments
  – Reading Transceiver status registers
  – Link startup, initialisation and configuration
  – Link status checking
  – Link recovery and re-initialisation
  – Calculation of the Signal Quality Indication
  – Activation of test and loopback modes
  – BroadR-Reach® specific service diagnostic routines

• No device wakeup by BroadR-Reach®, or Power over BroadR-Reach®, considered for first implementation
Choice of simulation and analysis tools now available with BroadR-Reach® interfaces

Vector tools used to validate Diagnostics and Transceiver driver software in JLR BroadR-Reach® physical layer implementation
BROADR-REACH® CHALLENGES

• Knowledge of Ethernet in Automotive supply base
  – Investment to introduce new technology, industry take-up not clear
  – E.g. 18mm max untwist at connectors – can we do +/- 30mm?

• Knowledge of Automotive in Ethernet technology suppliers
  – Automotive requirements a surprise – what’s EMC?
  – New chipsets, size, ratings, history from consumer applications
  – 150DegC – really? What’s wrong with a square inch? Just fit a big fan?

• Fear that BroadR-Reach® would be proprietary / single source
• Configuration of the Ethernet Network Protocol Stacks
  – Audio / Video stream reservation
  – Format and packing of Audio / Video streams

• Standards available, but Pro-Audio, not aimed at Automotive
  – Require serious processing capability
  – Optimisation required for Automotive
Data types to be transported in an infotainment system
- Time critical Audio and Video streams
- Deterministic command and control signals
- Best effort IP file transfer and packet data

Audio enabled by Audio Video Bridging (AVB)
- But choices and optimisations had to be made
• Data flows determined at design time
  – Required bandwidth for Audio streams, video, command and control, and best effort data assured by design

• Several variables are fixed in the system design
  – Number of streams, end points, channels in the streams…

• Key advantages
  – Simpler configuration
  – Fast start up
  – Only a subset of AVB protocols required
  – Lower processing requirements (interrupt loading!)
  – Less potential failure modes to mitigate
The following AVB standards are used in Infotainment:

- **IEEE 802.1Q VLAN**
- **IEEE802.1AS** Timing and Synchronization for Time-Sensitive Applications (gPTP)
- **IEEE802.1Q 2011**: Clause 34 - Forwarding and Queuing for Time-Sensitive Streams (formerly IEEE802.1Qav)
- **IEEE1722a**: Layer 2 Transport Protocol for Time Sensitive Applications in a Bridged LAN
- The relevant parts of IEEE 1588 Precision Time Protocol are contained within IEEE 802.1AS
• **OPEN Alliance** – One Pair EtherNet Special Interest Group  
  – Over 250 member companies, including most car makers. Formed to accelerate take up of Ethernet in Automotive  
  – Standardise BroadR-Reach, fill gaps in the Ethernet standards  
  – JLR a Promoter member and has run Technical Committees  
• **IEEE** – Home of the Ethernet standards  
  – Now working with Automotive to include our requirements  
• **AVNu** – Promoting and enabling the use of AVB standards  
• **AUTOSAR** – Ethernet support in Release 4.2.1
IEEE 802.3bw 100BASE-T1: Ethernet Standard to support 100Mbps over a single twisted pair cable, for operation in automotive environments. 100BASE-T1 will be the IEEE Standardised version of BroadR-Reach®

IEEE 802.3bp 1000BASE-T1: Ethernet Standard to support 1Gbps over a single twisted pair cable, for operation in automotive environments

IEEE P802.3bu 1-Pair Power over Data Lines (PoDL): Specifies a power distribution technique, designed to support voltage and current levels for the automotive industry, over a single twisted pair Ethernet link segment

IEEE P802.3bv Gigabit Ethernet over POF: a specification designed to support 1Gbps over Plastic Optical Fibre, for use in automotive environments
IEEE802.1 TSN Time Sensitive Networking (TSN); (formerly AVB2), a set of standards being developed to support time sensitive transmission of data over Ethernet networks

- 802.1AS-2011/Cor 1 - 802.1AS-2011 - Technical and Editorial Corrections
- 802.1ASbt - Timing and Synchronisation: Enhancements and Performance Improvements
- 802.1Qbu - Frame Pre-emption
- 802.1Qbv - Enhancements for Scheduled Traffic
- 802.1CB - 802.1CB - Frame Replication and Elimination for Reliability
- 802.1Qcc - 802.1Qcc - Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
THE GREAT BENEFITS OF ETHERNET

• Scalability – speed up individual links when more bandwidth required
  – Higher layer protocols and application software independent

• Switched network – Bandwidth added when a new ECU added

• Freedom to use the bandwidth in different ways
  – E.g. Higher layer software protocols for synchronisation

• Leverage the consumer and telecoms industries
  – Every other industry is using it, or planning to use it

• Taught in Universities and Colleges as standard

• “Fast, Simple, and Cheap!” quote from Stephen Carlson, IEEE
The future for JLR and others could look like this:

- **Ultra High Speed**
  - E.g. <1G+
  - Sub-Domain ECU
  - Domain 1 ECU

- **High Speed**
  - E.g. 10-100M
  - Sub-Domain ECU
  - Domain 2 ECU

- **Mid Speed**
  - E.g. <1M
  - Sub-Domain ECU
  - Domain 3 ECU

- **Low Speed**
  - E.g. <20K
  - Sub-Domain ECU
  - Domain 4 ECU

Domains could be functional – Sensing, Motion, Handling...
Or maybe locational – Front, Cabin, Rear...

Increasing Network Bandwidth
Logical cascade of network bandwidth
100/1000Mbit Ethernet communication
Industry standard solutions for Ethernet
at all layers below applications
Shift from a: Collection of ECUs connected by networks

To a: Distributed computer network, programmed as a car!
THANK YOU! - QUESTIONS