MICROSYM COMPUTERS INC.

Tunneling Routers for Trainline Networks

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Trainline Realities

- **Number of trainlines is limited**

  Trainlines are required for power, control signals, etc. Some trainlines must be duplicated for redundancy. The number of trainlines that can be connected across an automatic coupler is limited. Since trainlines are limited, using multiple trainline pairs for control networks, audio, etc. is not an option.

- **Connections across automatic couplers are difficult**

  Automatic couplers are designed to handle DC and low-frequency signals. Wabco and other coupler manufacturers are investigating high-speed connection solutions, but these are not yet readily available.

- **Expensive hardware is used to multiplex trainlines**

  In order to deal with the trainline situation, electronics on both sides of the coupler is used to multiplex multiple audio and EIA-709.3 channels over single pair trainlines. An example of this is the TMX (Trainline Multiplexer) built by Telephonics, for NYCTA subway trains (R142, R142A, and R143). In this case and E1 network is used for the trainline.

- **Trainlines are subject to extreme noise and environmental conditions**

  Electric trains present large bursts of noise to the network, due to arcing from the third rail. Trains operate in all weather conditions, and couplers are subject to grease, dirt, and other contaminants.

EIA-709.3 (FTT-10) Channel Throughput

- **Nominal TP/FT-10 channel capacity is ≈190 pkts/sec (sustained, 12B pkt)**

  Based on the output of the Echelon® PERF utility, the sustained capacity of an FTT-10 channel, transporting 12 byte packets, would be approximately 190 packets per second.

- **Channel propagation delay has large impact on bandwidth**

  For any LonTalk® (EIA-709) channel, the dead space between packets will be an average of approximately 26 times the maximum channel propagation delay. This is to accommodate the CSMA algorithm used by the protocol. For most networks this is not an issue, but this can have a major impact for networks with multiple repeaters or buffer delays.

- **Propagation delay over an E1 channel reduces capacity to 30 pkts/sec**

  The delays introduced by synchronizing EIA-709.3 messages with E1 add/drop logic and the slip buffers result in a maximum channel propagation delay of around 1.2ms. This results in a required inter-packet gap of more than 31ms. With the addition of packet data, this results in a channel capacity of only 30 packets per second.

- **Proprietary E1 transceiver design for Telephonics substantially improves this**

  A proprietary E1 transceiver designed for Telephonics by Microsym improves the capacity over an E1 channel, but it is still not as good as a clear EIA-709.3 channel. Microsym is not authorized to use this technique for other customers.

Gateway Solution

- **Use something other than EIA-709 over high propagation delay channels**

  To eliminate the propagation delay problem, some other network and protocol can be used over the trainline network, while still using EIA-709 networks in each rail car.

- **This implies a foreign network and protocol, with gateways to EIA-709 channels**

  Every rail car would then need a gateway between the trainline network and each EIA-709 channel in each car.

- **Complicates network design and commissioning**

  Gateways are problematic because they must understand both networks and protocols, and all variables being exchanged. This is a software and documentation nightmare, especially for transportation systems where documentation requirements are stringent.

- **Allows transport of other information (audio, video, etc.) over same network**

  Aside from the throughput benefit, gateways permit multiple types of information to be transported over a single network. A sufficiently high-speed trainline network could accommodate multiple EIA-709 networks, audio channels, and video channels.

Packet Tunnel Alternative

- **A packet tunnel is like a gateway with one variable**

  A packet tunnel is a special kind of gateway. If the gateway has one variable, and that variable is 'EIA-709 message', then every EIA-709 message received could be transported over the foreign protocol, regardless of the message contents. So then, a packet tunnel is effectively a store and forward repeater. This greatly simplifies development, documentation, and support compared to a typical gateway.

- **All EIA-709 messages received at one packet tunnel are retransmitted by other packet tunnel(s) on the network**

  If multiple packet tunnels are connected to the foreign network, then the other packet tunnels can retransmit an EIA-709 message received by one packet tunnel.

- **Propagation delay problem is eliminated**

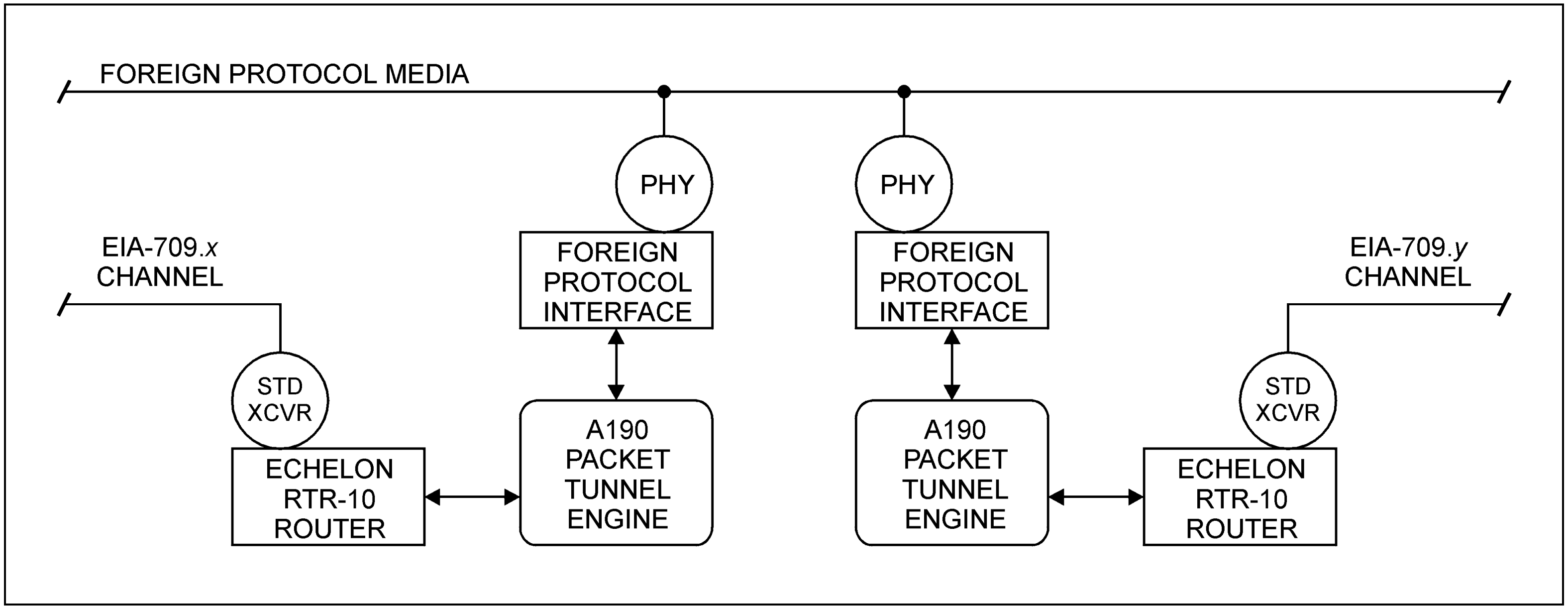
  Use of a foreign protocol that is not dependent on channel propagation delay will eliminate the interpacket gap problem. Each EIA-709 channel on a packet tunnel can use MAC timing that assumes no channel propagation delay. There is message latency (channel delay) between the packet tunnels, and this will normally be in the order of one packet time plus a few milliseconds.

- **The Microsym A190 Packet Tunnel has been developed for this application**

  The A190 is a packet tunnel engine, which implements the interface between an EIA-709 network and a foreign network. The foreign network connection and protocol must still be implemented external to the A190.

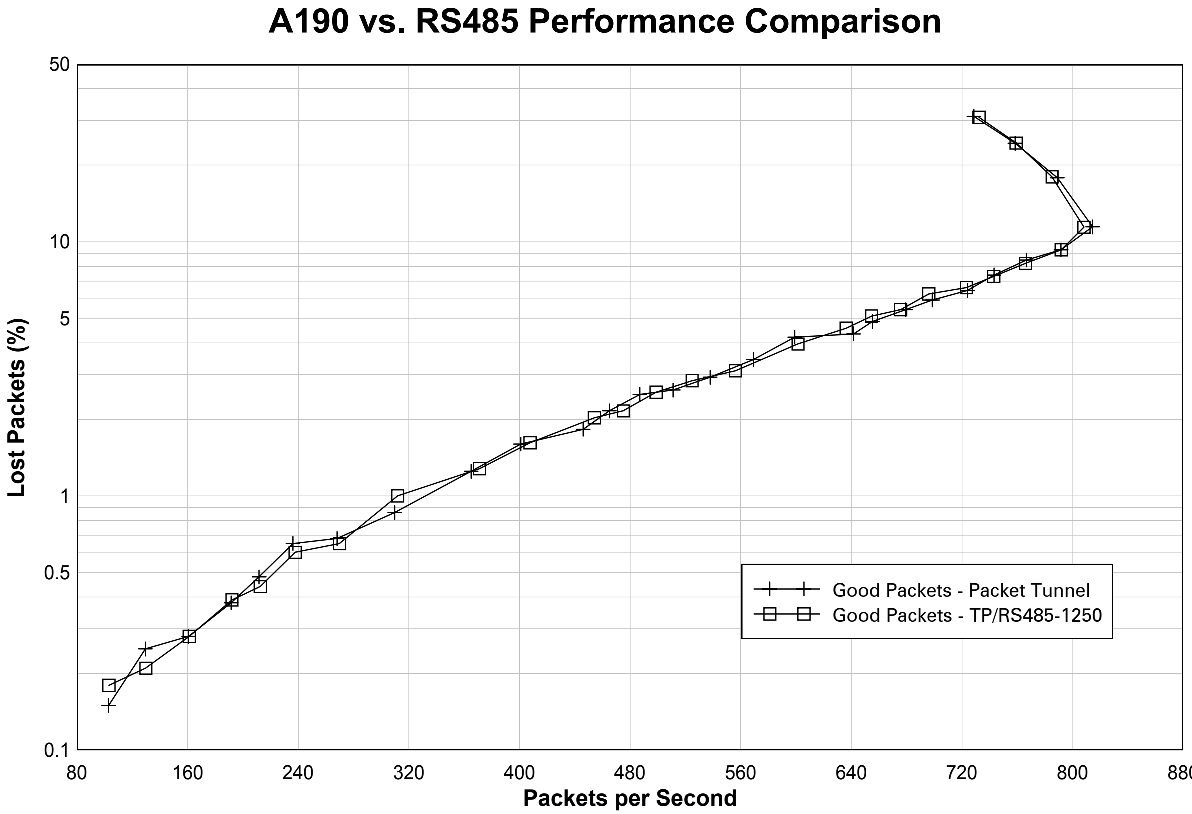
Tunneling Router Implementation

The Microsym A190 Packet Tunnel, in conjunction with an Echelon router and foreign protocol interface, provides a tunneling router solution. This provides the greatest flexibility, since a different EIA-709 channel type can be used at each tunneling router. The A190 Packet Tunnel includes a 64-packet buffer.



Tunneling Router Performance

- **Tested at 1.25Mbps, the Tunneling Router performance is equivalent to two Echelon RTR-10 Routers connected back-to-back (via RS485)**



A190 Packet Tunnel

- **Allows full EIA-709 bandwidth to be carried over foreign protocols.**

  Depending on the bandwidth available on the foreign network, a number of EIA-709 channels can be multiplexed over the network using multiple A190s.

- **Industrial grade components and construction**

  All components used are industrial temperature rated. The A190 is supplied as a module that can be soldered down to the target board. Electrolytic and tantalum capacitors are not used. There are no sockets on the A190, and the A190 can be supplied conformally coated. The A190 requires 5VDC and 3.3VDC power, and total power consumption is 1.1W.

- **No special Echelon licenses required**

  The A190 does not contain a custom EIA-109 protocol implementation, and does not use special-purpose mode transceivers.

- **Compatible with Echelon LNS™ based tools**

  Tunneling routers using the A190 are fully compatible with Echelon LNS based tools, including LonMaker™ for Windows.

Possible Trainline Networks

- **PDH (E1 in use now, E3 or T3 for future use)**

  PDH (Plesiochronous Digital Hierarchy) encompasses levels T1 through T4 and E1 through E5. E1 (2.048Mbps) is currently being used for trainline networks. T3 (44.736Mbps) is a good candidate for future trainline networks. Components are readily available in industrial temperature range. The physical layer can be implemented in copper (coax) or fiber optics.

- **SONET/SDH**

  SONET (Synchronous Optical Network) and SDH (Synchronous Digital Hierarchy) networks are implemented at STS-1 bit rates (51.84Mbps) and higher. The physical layer is typically implemented using fiber optics.

- **ATM**

  ATM (Asynchronous Transfer Mode) networks are implemented at a wide variety of speeds, over twisted-pair, coax, and fiber-optic networks. Components are available from many sources.

- **AS-5370**

  AS-5370 from CBL Systems is an option, but the network speed is limited. Video over AS-5370 would be problematic. AS-5370 is currently available for aircraft use only.

Possible Trainline Networks (cont.)

- **TCN-WTB**

  TCN-WTB (Train Control Network - Wire Train Bus) is an approved standard (IEEE-1473) for trainline network use. Unfortunately, at 1Mbps it is obsolete from a bandwidth requirement perspective. There is no growth path for TCN, and it is proprietary. The TCN specification is complex, and implementation would be difficult.

- **Profibus, SwiftNet, WorldFIP, etc.**

  There are several field busses that could be applied to trainline networks. The speed of these networks is limited, so video over these networks would be problematic.

- **Ethernet**

  There is a lot of talk these days about industrial Ethernet, but these industrial grade networks use hubs with full-duplex connections to the nodes. This eliminates the possibility of collisions, which caused major latency problems on the old10-Base2 and 10-Base5 coax Ethernet networks. Unfortunately, a trainline cannot be wired in a hub configuration, so this would force the use of a multi-drop coax network. This would be prone to collisions and resulting latency problems, and is therefore unsuitable. Also, Ethernet components are very hard to find in industrial temperature range.

Trainline Networks Table

PROTOCOL	SPEED	MEDIA	LATENCY	WORK EFFORT	LON MUX	AUDIO / VIDEO	PROS	CONS
LONWORKS® EIA-709.3	78Kbps	TP	Low	None	No	No	Established, used by NYCTA and others	Low speed, no mux, no A/V
AS-5370 (LONWORKS Derivative)	1.25Mbps 5Mbps	TP, Fiber	Low	Small	Yes	Audio	Fiber, deterministic, FAA certified	5Mbps under development, licensing issues
TCN WTB	1Mbps	TP	High	Large	Limited	Maybe some audio	Promoted by Siemens and Adtranz	No growth path, latency, no A/V
Ethernet	10Mbps	Coax	High	Medium	Yes	Yes	Widespread	Latency, coupler issues, parts commercial grade
Profibus	12Mbps	TP, Fiber	Low	Medium	Yes	Audio, maybe video	fast	Parts & s/w from several sources, coupler issues
E1 PDH	2.048Mbps	TP	Low	Small	Yes	Audio	Established, used by NYCTA	No growth path
WorldFIP	2.5Mbps	TP Fiber	Medium	Medium	Yes	Maybe some audio	Promoted by Alstom	Custom components, European
ATM	25.6Mbps 51.8Mbps 155Mbps 622Mbps	TP, Coax, Fiber	Low	Medium	Yes	Yes	Fiber, fastest, widespread, parts availability	Asynchronous, cost, coupler issues
SONET/SDH	51.8Mbps 155Mbps 622Mbps	Fiber	Low	Medium	Yes	Yes	Fiber, fastest, synchronous	Cost, coupler issues
T3 PDH	44.736Mbps	Coax, Fiber	Low	Medium	Yes	Yes	Fiber, fast, parts availability	Coupler issues

Trainline Development Path

- **One trainline network will be selected**

  Within the next few months, one foreign network will be selected for a proof-of-concept implementation. This selection will be made after consultation with car builders, coupler manufacturers, and standards groups.

- **T3 PDH will most likely be the network used**

  At this time, we are leaning towards an implementation based on T3 (PDH). Industrial grade components are readily available, and this can be implemented over copper and fiber optics. E1 trainline networks are already in revenue service, so there is some relevant experience and with using PDH and telecom grade networks for trainlines.

- **Proof-of-concept network will demonstrate multiple EIA-709.3, audio and video channels over one trainline network**

  The initial demonstration will transport the following over the trainline network:
  - A few EIA-709.3 networks
  - A few voice-grade audio channels
  - One or two video channels (MPEG or wavelet compressed)

- **Environmental, EMI, and RFI tests to be performed**

  Testing will be performed to establish suitability and reliability of the network for trainline use. We hope to enlist the aid of one or more car builders in this exercise.

Conclusion

- **High-speed trainlines are required for future trains**

  Future trainline networks will require bandwidths in the order of tens of megabits per second. This is needed to transport multiple EIA-709, audio, and video channels over the trainline. New trainline network technology will have to be developed and tested to facilitate this. Automatic couplers will require further development to support high-speed networks.

- **Tunneling routers will allow multiple full-bandwidth EIA-709.3 channels to be transported over the high speed trainline**

  In order to transport full EIA-709.3 bandwidth over a trainline network, a tunneling router is needed to overcome the effects of propagation delay. A tunneling router is implemented using an Echelon router, a packet tunnel engine, and a foreign protocol interface.

- **The Microsym A190 Packet Tunnel facilitates implementation of efficient tunneling routers**

  The Microsym A190 Packet Tunnel provides the packet tunnel engine needed to implement a tunneling router. The A190 is compact and rugged, suitable for rail applications.

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