# Ethernet 101 for Automotive


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# Agenda

- Networking Technology & Standards
  - Ethernet the way it really is!
- Ethernet In-Vehicle Networking
  - Using Ethernet in a constrained/controlled environment
  - Ethernet PHY example roadmap

# What am I trying to show?

- Ethernet already has the fundamental toolkit in place
  - and there is a huge market and technology momentum
  - highest performance, lowest cost, widest adoption (proven)
- Adapting Ethernet to vehicular requirements is straight-forward
  - and has significant fundamental advantages over the alternatives
  - AVB (now) and AVB gen 2 (future) provide the next set of tools
  - physical layers optimized for automotive and control applications

## Ethernet 101:

# The way it really is

- All links run at 100 Mb/s or faster
  - 1 Gb/s links are now outselling 100 Mb/s
  - 100 Mb/s is “free” (included in most consumer-electronics-based SoC’s)
- Ethernet is a switched network
  - there are no shared media (e.g. hubs, repeaters)
  - “CSMA/CD” is dead, there is no “media access protocol”
- Ethernet switches are really smart
  - priorities, virtual LANs, QoS by deep packet inspection
  - “spanning tree” and “shortest path bridging” eliminates loops
  - “link aggregation” takes advantage of redundant paths

Ethernet 101:

# The way it really is (cont.)

- Ethernet PHYs are really smart
  - automatic pair alignment
  - cable diagnostics (impairment measurement and location)
- Ethernet runs on all kinds of media
  - UTP (1-pair for BroadR-Reach, 2-pair for 100Mb/s, 4-pair for 1Gb/s and 10Gb/s)
  - STP (10G short range)
  - optical fiber (multimode or single mode, silica or plastic)
- Ethernet does not have to run at “decade” rates
  - 2.5G widely deployed in data centers
  - “SONET” infrastructure used for Ethernet links as well

## Ethernet 101:

# Security

- Switched network, remember?
  - All connections are point-to-point, not shared
- "MACSEC" is a hop-by-hop, link-specific security system
  - Devices on each end of a wire link can encrypt data just for a known device on the other end
  - Extended to support login (same technique used in "WPA" for WiFi)
  - Extended further to support robust device ID

## Ethernet 101:

# The way it is coming to be

- 10 Gb/s deployment is ramping up
  - currently data center and telecom / short range copper / long range fiber
  - UTP (four pair Cat 6a ramping for data center / video)
- 40 and 100 Gb/s standardization complete
  - for optical fiber ribbon
  - new project for shielded twisted pair (STP)
- “Energy Efficient Ethernet” standardization is complete
  - automatic and very fast power scaling with traffic requirements
  - deployed NOW
- “FireWire”-type streaming QoS services coming soon
  - IEEE 802.1 Audio Video Bridging
- Congestion management for data
  - “no dropped packets” IEEE 802.1au, 802.1bb

## Ethernet 101:

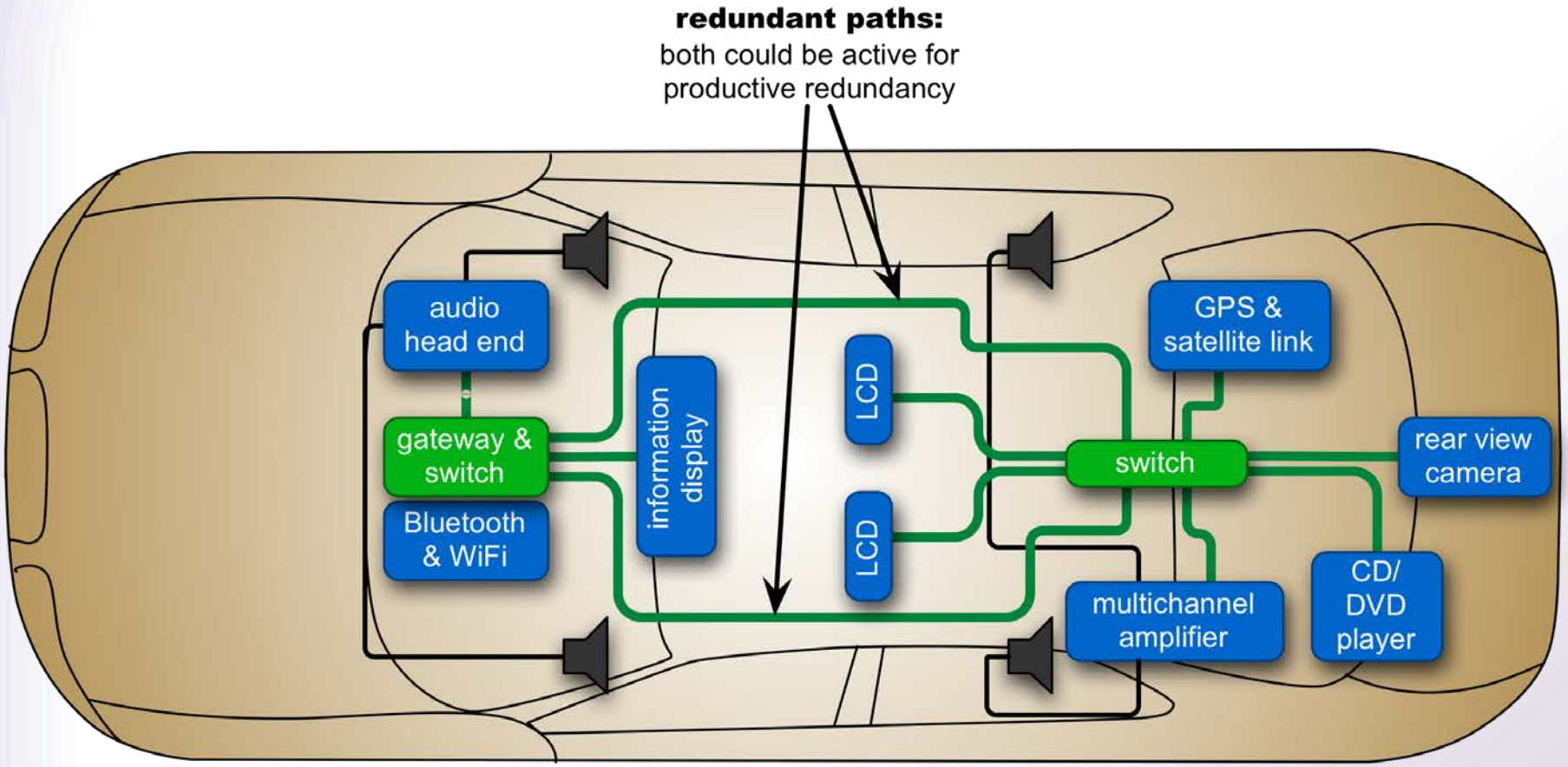
# Synergies

- Almost all networked devices have an Ethernet port
  - least common denominator
- Baseline assumption for IP networking
  - must work on Ethernet
- Baseline network for DLNA
  - along with WiFi
- Market volumes are *huge*
  - Broadcom alone shipped over a billion ports by 2004
  - Technology and production investment continues

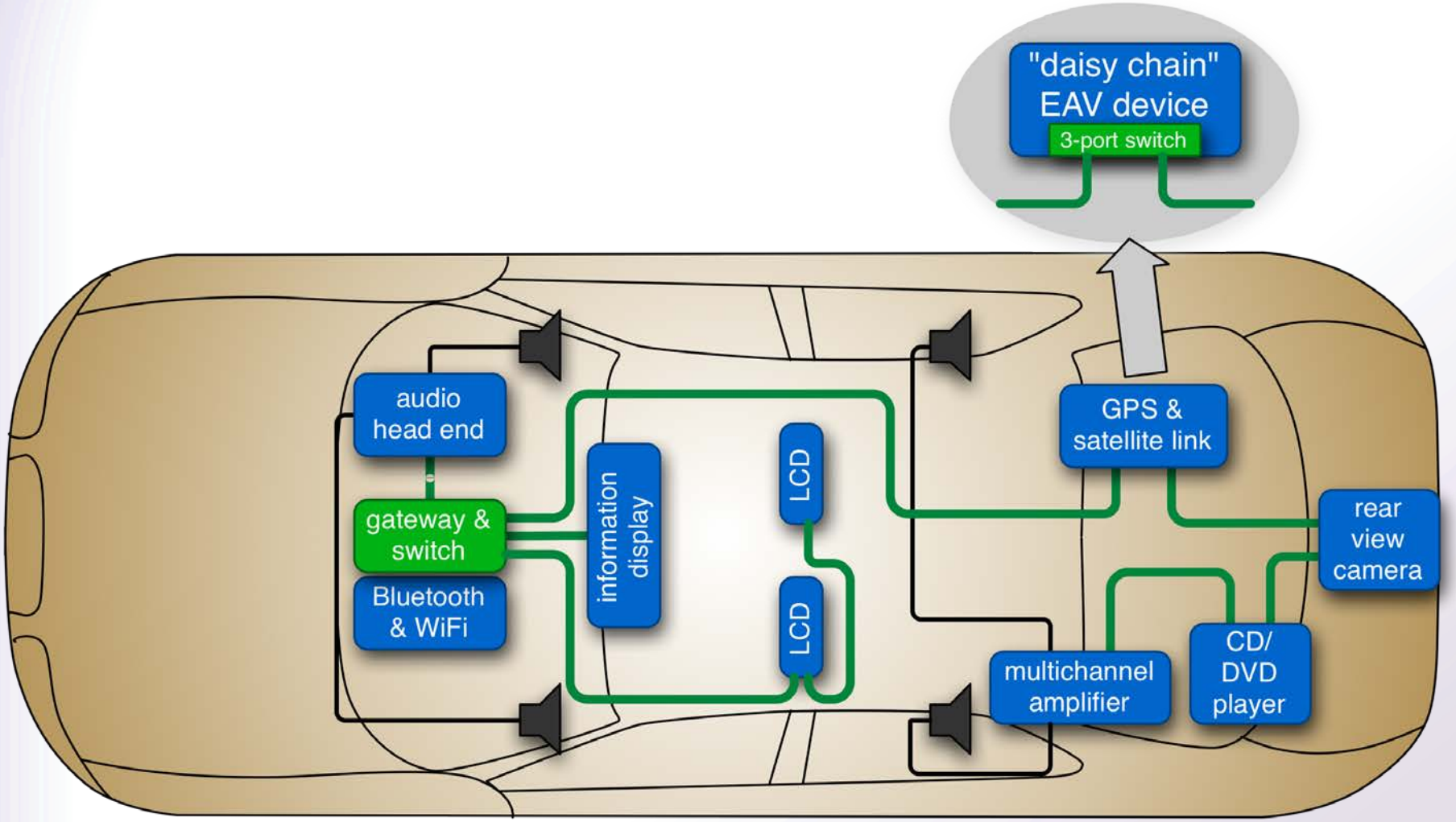
# How do we use it?

- Enormous flexibility in deployment
- Ethernet switching standard allows for
  - many cable hops
  - star, daisy-chain, ring … **any** topology
- Rings or meshes OK for redundancy
  - "spanning tree" will disable redundant links
  - or redundant links can be used together in "link aggregation"
- Devices can have built-in switch to encourage daisy-chaining
  - currently done with VOIP phones

# Topology with redundancy



# Topology without redundancy



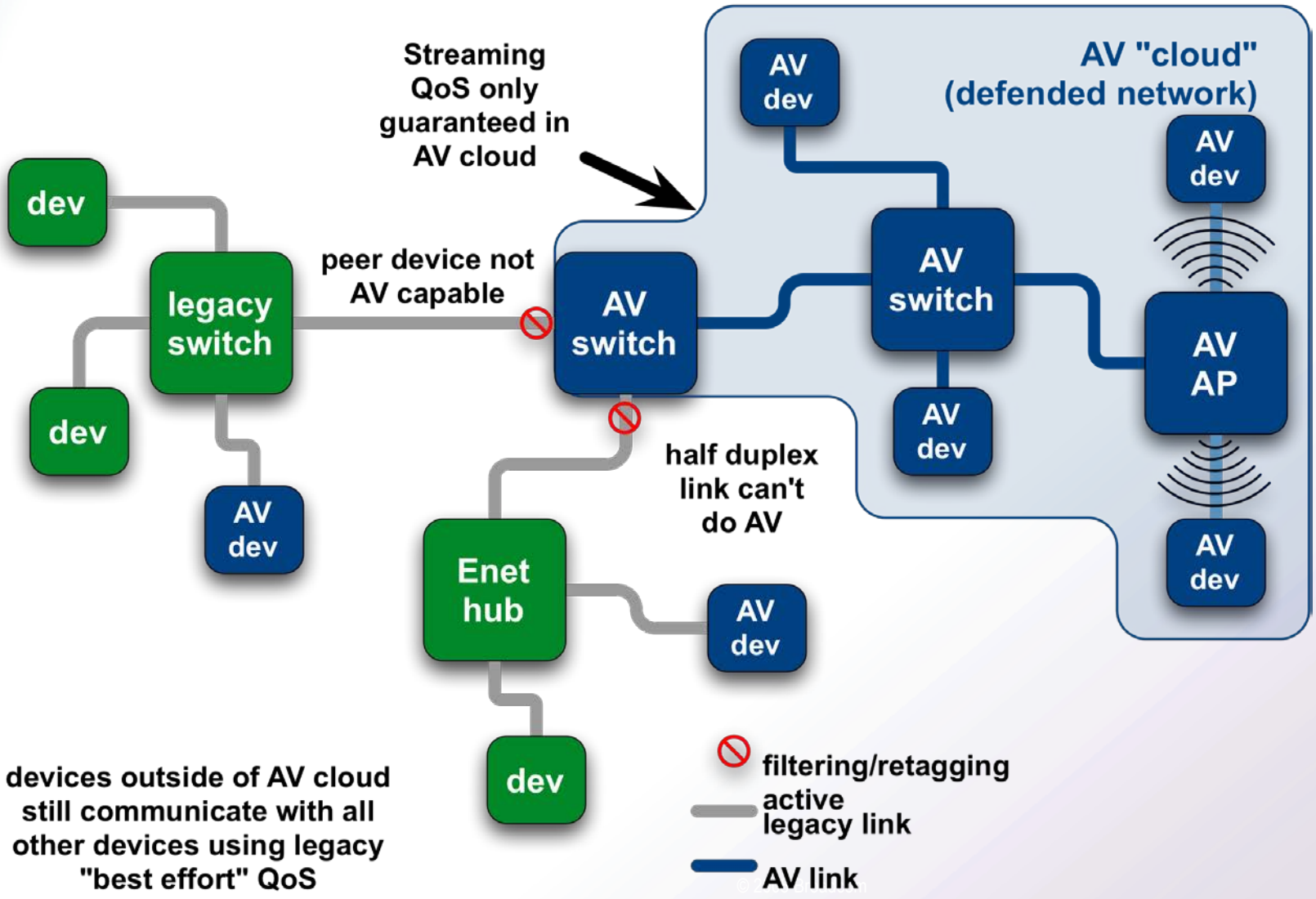
# IEEE 802.1 Audio Video Bridging

- The IEEE 802.1 AVB Task Group was responsible for developing standards that enable time-sensitive applications over IEEE 802 networks
  - the IEEE 802.1 Working Group is responsible for bridging (including Ethernet “switches”)
  - interoperability between networks of differing layer 2 technologies
- The primary projects completed:
  - queuing and forwarding of time-sensitive streams (“credit-based shaper”) – part of IEEE Std 802.1Q-2012 “VLAN networks”
  - registration and reservation of time-sensitive streams (“stream reservation protocol) – part of IEEE Std 802.1Q-2012 “VLAN networks”
  - time synchronization (“generalized Precision Time Protocol – gPTP”) – IEEE Std 802.1AS-2011
  - overall system architecture (IEEE Std 802.1BA-2011 “Audio Video Bridging Systems”)

# Unified Layer 2 QoS

- Enhance network bridging
  - Define common QoS services and mapping between different layer 2 technologies
  - IEEE 802.1 is the common technology
- Common endpoint interface for QoS
  - “API” for QoS-related services for ALL layer 2 technologies
  - Toolkit for higher layers
  - Provide network independence for endpoints without giving up QoS

# AVB services only in the “AV cloud”



# Audio Video Bridging Services

- 2 ms bounded latency through 7 Ethernet bridges
  - linear relationship with the number of bridges
  - delays through cooperating 802.11 systems TBD, but much longer
- SRP reserves link resources
  - For Ethernet, bandwidth is the primary resource
  - For coordinated shared media (802.11, G.hn, MoCA) resource management is more complex
- Precise timing and synchronization services for timestamps and media coordination
  - < 1µs instantaneous synchronization between devices
  - delivered clock provides a reference that can meet the jitter and wander requirements (MTIE mask) for HD-SDI and AES audio streams

# New services / technology / standards

- Ethernet is in continuous development
- New physical layers
  - 40GbaseT, reduced-pair PHYs
- New reliability enhancements
  - Multiple paths / simultaneous paths for critical traffic
- New delay reduction technologies
  - Scheduled queues, preemption, burst limiting queues
- These could all be parts of “AAA2C”
  - But they are going to be standardized / deployed in any case

# An example “new technology”

- Ethernet designed for much longer distances
  - UTP for 100m
  - 3 connector interfaces in series (jumper-backbone-jumper)
- Perhaps we can use this for extra margin to gain resistance to interference?
  - example: Broadcom’s “BroadR-Reach” PHYs use 1G technology to go 500m at 100 Mb/s using 4 pair or even 500m over a single pair at 10Mb/s
    - Lower cost replacement for DSL
  - Use the same idea to provide Ethernet unshielded single pair PHY operating at 100 Mb/s
    - Uses same concept as 4x UTP 1GbaseT
    - Uses existing auto cable/connector technology

# Layer 2 Technology Roadmap

- Possible new generation reduced pair UTP (wired connections for automotive and control)
  - 250baseOneT (using lessons from 100) - a few years
  - 1GbaseOneT (using lessons from 250 and standard 10GbaseT) - a few more years
  - 2.5GBaseOneT (or 2.5GBaseTwoT) - maybe 6-8 years
  - (Maybe two pair … not decided yet)
- Wireless
  - 2.4GHz/5GHz 802.11 can be AVB compliant (802.11v and 802.11aa updates) – up to 1Gb/s, with variable QoS
  - 60GHz "WiGig" can be AVB compliant (802.11ad), good for short range … inside passenger compartment

# Automotive AV network comparison

| | Ethernet AVB + BroadR-Reach | MOST | IDB-1394 "FireWire" |
|---|---|---|---|
| Architecture | switched | shared synchronous ring | shared bus |
| Topology | star, daisy-chain, ring –all with optional ***productive*** redundancy | ring | star, daisy-chain, ring - all with optional redundancy |
| Bandwidth | 100 Mb/s, 1000 Mb/s, 10 Gb/s widely deployed – 40/100 Gb/s in development – many other rates used in private networks … ***per link*** | 25 Mb/s common, 150 Mb/s in early deployment … ***shared*** | 100, 200, 400, 800 Mb/s widely deployed – 1.6Gb/s in prototype, 3.2Gb/s specified … ***shared*** |
| Medium | single UTP (Flexray or equivalent at 100 Mb/s), multiple UTP/STP, coax, all types of fiber | Plastic Fiber, UTP | fiber and STP up to 800Mb/s, UTP to 100Mb/s – UTP up to 800Mb/s specified |
| Sample rate / time synch support | Any arbitrary native rates<br>~ 100 ps jitter - <1 us synchronization | 44.1 KHz native, sample rate conversion for other rates | Any arbitrary native rates<br>~ 100 ps jitter - <1 us synchronization |
| Diagnostics | Built-in Cable Diagnostics that checks open, short, location of fault, quality of the medium. | ?? | ?? |
| Cost | Low-cost, approaching analog system, many billions of ports deployed | Higher, less than a million ports deployed | Higher, no deployment, but over one billion 1394 ports |

# Conclusion

- Ethernet offers true networking at competitive costs
- Data rates are compatible with automotive and control use cases now
  - With a robust technology road map
- Quality of Service is compatible with camera/audio/ video use cases
  - Bounded latency, guaranteed bandwidth, precise synchronization
  - Improvements in the pipeline for control applicaitons
- Modest reuse of existing technology for auto use
  - Existing auto-qual single unshielded twisted pair and connectors

Thank you!