Networks In Motion:
Fiber Optic Communication in Vehicles

Presentation by
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Engaging A "Network In Motion"

- "Mobility" no longer just a phone/laptop;

- Now, a *Network in Motion* enables a rich data network surrounding you with your devices and an "active environment";

- To enable this level of connectivity, wireless and fiber optic transport should emerge as the dominant topologies (similar to the way wired ethernet dissolved 10-15 years ago)

- The Automotive supply chain will change as separated systems become networked and have more Telematics content

What is a Network in Motion?

- Software Driven/Self Driving Automobiles/ADAS platforms could have ethernet 802.3cz networks
  - There are 13 million cars sold each year
  - About 500,000 trucks, 1 million farm vehicles and 1-2 million heavy industry vehicles...close to 15 million nodes put in motion/year
- NOTE: There are about 275 million PCs sold/year
- Networks in Motion could have 10-20 nodes, so overall network nodes could jump 50-60%!
- These nodes will have timing requirements unlike other mobile networks (safety, status)
- And liabilities tied to the transport of information
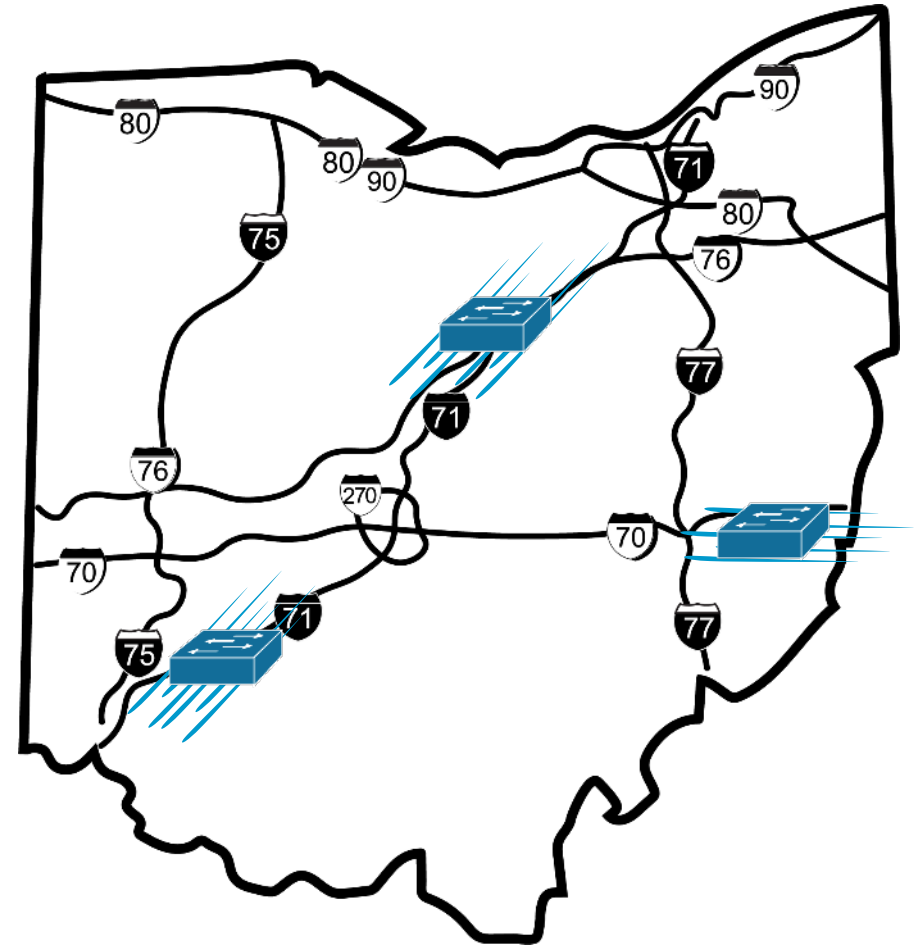
What Could be a Network Node?

1. Power connector
2. Computing system
3. Electrical or optical data connector
4. Environmental sensors
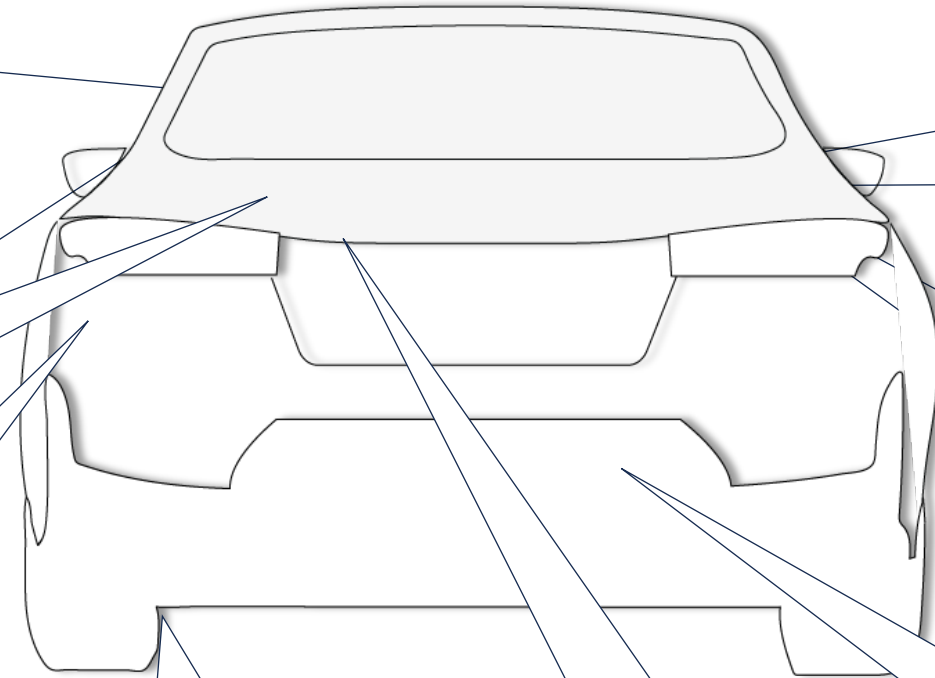5. Batteries (backup)
6. Enclosure
7. Application

980 VCSEL per 802.3cz PIN Diode Controller Connectors

Cabling in the vehicle will require multi, single, splitters, taps, and possibly WDMs

GOF or POF?

Fiber connectors "To Be Determined!" Single ferrules difficult to maintain, MTs even harder, while expanded beam too $…so?

Power Network much larger part of vehicle with very large voltage differentials from system to system as well as operational support to idling support, all on an 802.3 network
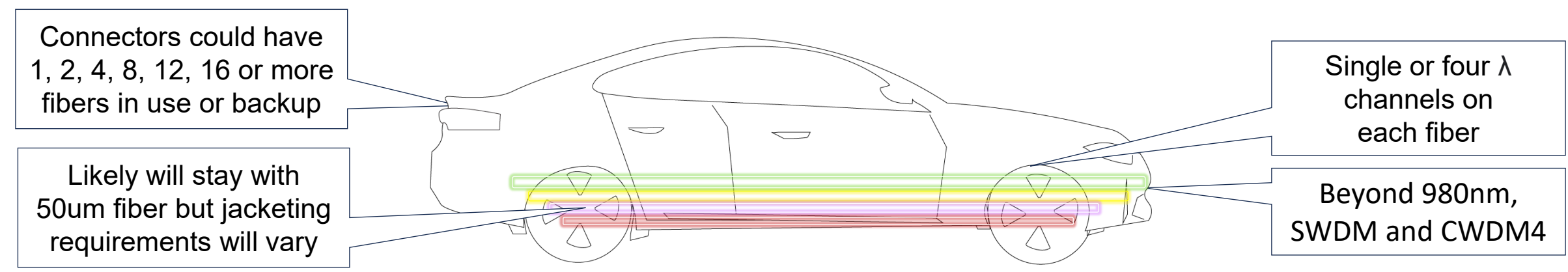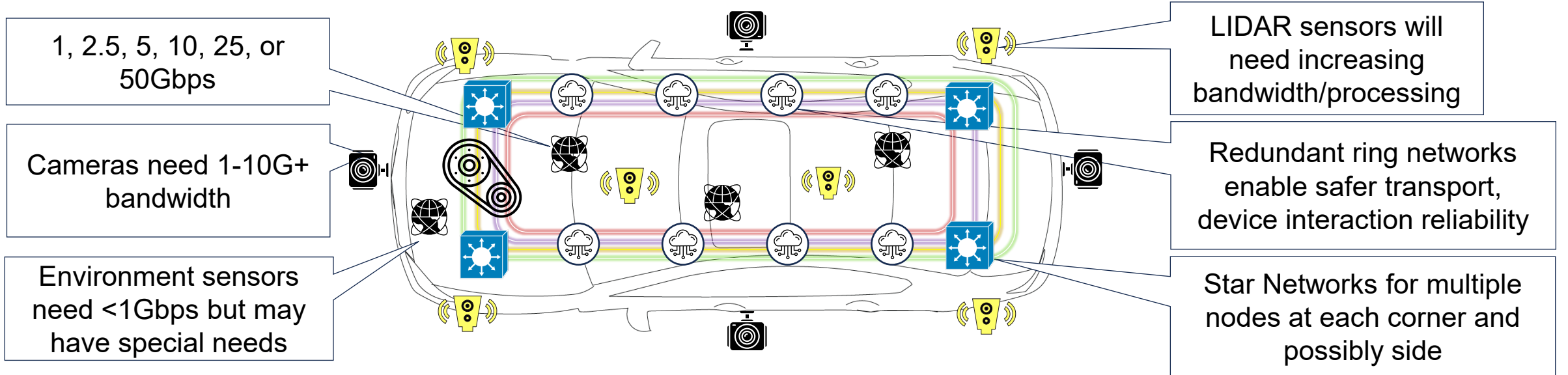
Driving Systems Network is new and likely will be upgraded often and remotely. With multiple ECUs, redundancy, last gasp, use tracking, and occupant interaction are complex

Engine Systems for modern and neo modern engines (electric or other hybrid). The number of sensors and need for a sensor network is pressing and could be accomplished with fiber optics

Communication Systems for vehicle-to-cloud and vehicle-to-vehicle
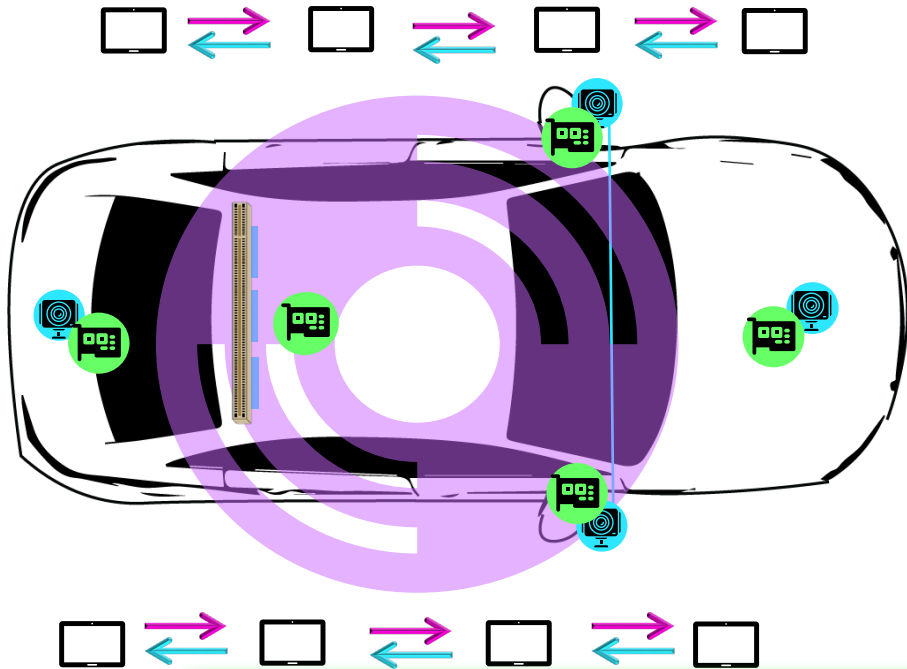
Cabin systems for connecting to existing mobile devices and non-vehicle operation electronics

Fiber Network in a Vehicle and Applications

1, 2.5, 5, 10, 25, or 50Gbps

LIDAR sensors will need increasing bandwidth/processing

Cameras need 1-10G+ bandwidth

Redundant ring networks enable safer transport, device interaction reliability

Environment sensors need <1Gbps but may have special needs

Star Networks for multiple nodes at each corner and possibly side

Connectors could have 1, 2, 4, 8, 12, 16 or more fibers in use or backup

Single or four λ channels on each fiber

Likely will stay with 50um fiber but jacketing requirements will vary
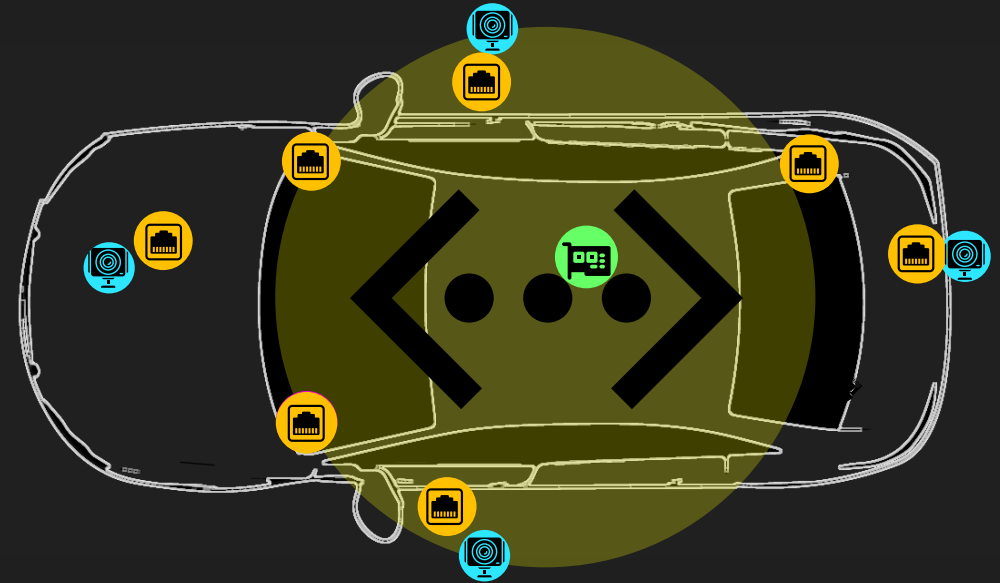
Beyond 980nm, SWDM and CWDM4

Could PCI Express Be Better Than Ethernet?

PCI Express Fabric VS ETHERNET

Network needs vary in latency, response, priority, bandwidth, redundancy, more.
Not everything needs to be Ethernet, but everything may need to report status that way.

Key Fiber Network Components

RJ-1G 980nm VCSEL at 1.0Gbps **[T$_{op}$ = -40°Cto105°C, V$_{cc}$ = 3.3V]**

Parameter	Symbol	RJ Specifications			Performance Test Result			Unit
		Section	MIN	MAX	MIN	TYP	MAX	
TX Optical Modulation Amplitude (dB)	P$_{OUT}$	4.4.1.1	-1	4	-0.17	0.19	0.58	dBm
Rise Time	T$_r$	4.4.1.2	-	1200	55.6	65.4	73.3	ps
Fall Time	T$_f$	4.4.1.3	-	1500	93.3	107.3	140	ps
Total TX Jitter$_{p-p}$	TJ	4.4.1.4	-	250	15.6	24.8	31.1	ps
Optical Wavelength	λ$_C$	4.4.1.5	-	-	979	981.4	984	nm
Spectral Width	б	4.4.1.6	-	0.85	0.23	0.30	0.37	nm

RJ-1G 980nm at 100Mbps / 1Gbps **[T$_{op}$ = -40°Cto105°C, V$_{cc}$ = 3.3V]**

| Parameter	Symbol	RJ Specifications			Performance Test Result			Unit
		Section	MIN	MAX	MIN	TYP	MAX	
Sensitivity	P$_{in}$	4.6.1.1	-25		-29.6	-27.5	-25.3	dBm

980nm VCSEL at Temp with 24 dB of link budget shown.

Could be 28 or even 32 if needed

- Fiber cable, strand count, jacketing, marking
- Cable ties, rails, etc.
- Optical Transceiver: VCSEL/PIN/optical package, controller, driver, amplifier, optical and electrical connector, what diagnostics it offers, and what enclosure it has for automotive (lightweight but rugged)
- Network should accommodate upgrades, taps, splitters, and…dirt
- NOTE: vibration issues around modulation and hysteresis

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Benefits of Fiber

- Sensors can be on the fiber network with actuation interaction, optically

- Could a PON architecture reduce the number of ECUs and their complexity?

- Glass can be a sensor…may not need 100x new sensors, just new applications

- BiDi is now standard, shouldn't 802.3cz include any wavelength, as long as the devices meet the environmental defined by Automotive?

- Can more be done to enable car-to-car communication?

- Truck networking or farm vehicle may come first

- Air taxis could use the same devices and parts
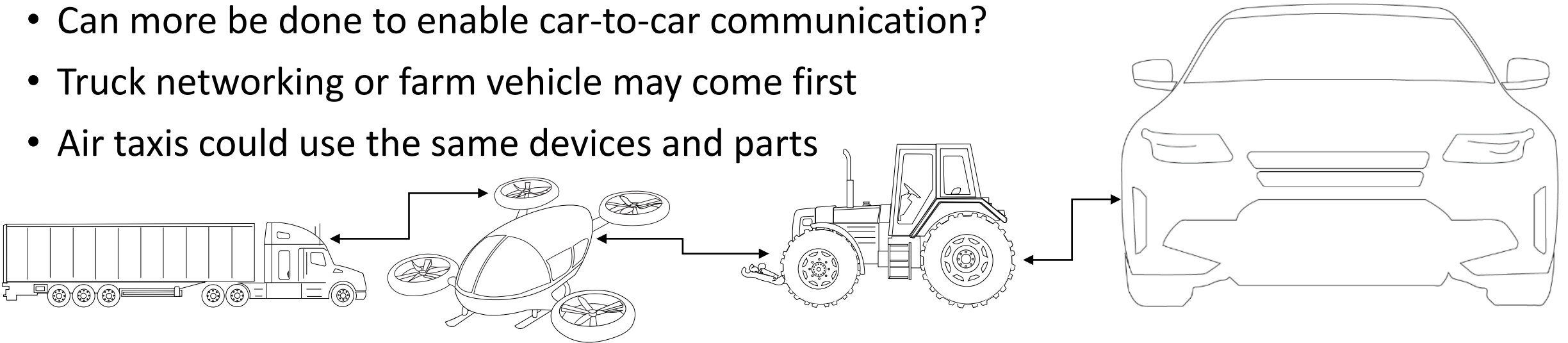
Industry Standards/Supply Chain Standards

- TIA/EIA or IEC covering fiber optic standards

- Automotive standards for wiring, especially vibe profiles

- Other ethernet specs for T1, POF

- SAE standards for fiber optics
  - Currently working on MT ferrule standardization in MIL 38999
  - Excellent resources for fiber handling in military harsh environments could be applied to automotive and help move deployment forward with service center engagement
  - Now looking at BER testing on passive connectors due to high-speed link requirements

- ARINC standards for fiber optics
  - Single ferrule and MT standards in place, rectangular connectors
  - Excellent resource for fiber handling in commercial aero

Thank You