MARVELL

Self-Diagnosis for In-Vehicle Networks

Ramin Farjadrad, Dance Wu, Peter Wu, Shaoan Dai

September 2020

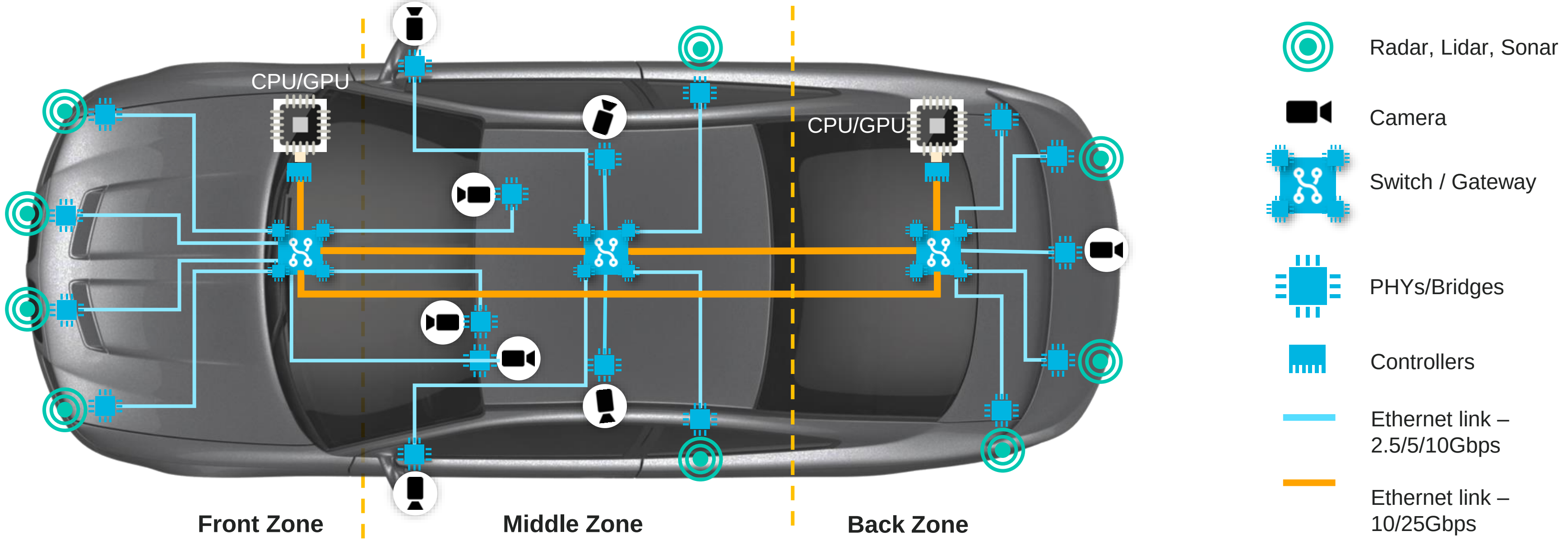
Background

- Today and future Autonomous Vehicles require highly reliable In-Vehicle Networks (IVN) to deliver on the need for massive amount of data communication.
- This ever-increasing need for very reliable and high bandwidth is driven by new trends such as
    - Artificial Intelligence (AI)
    - Machine Learning (ML) for data processing,
    - Time Sensitive Network (TSN)
    - Security
    - Smart power distribution over data line to minimize cabling

In-Vehicle Network Use Case

Multi-Gig camera/sensor bridges, PHYs and switches

Ethernet Backbone at speeds of 10G and 25Gbps



Why Self-diagnosis is Important

- Real-time self-diagnosis is a key element to meet system-level functional safety goals.
    - Self-diagnosis can provide real-time healthiness of the network
- IVN enables such capability across the entire network.
- The result can be used to determine channel behavior under realistic driving conditions as well as extreme EMC environment.
- With advanced data processing technology, such as AI and ML, more effective prediction of network healthiness is possible.

Failures Categories in Ethernet IVN

- Persistent Full Failures: Link Always Down
  - Damages in Cables/Connectors/ECUs Breaking the Network Link
- Persistent Marginal Performance: Link with High BER
  - Quality Degradations in the link component Impacting the Link Margin
  - Aging and/or faults in Cables/Connectors/ECUs
- Sporadic Failures: Occasional Link Down or High BER
  - Broken/Loose/Damaged Shield-Ground Connection of Cable/Connectors/ECUs Boxes
  - Loose/Bad Connections in the Network Links
  - Environmental noise

Failures Mechanism in Ethernet IVN

- Persistent: Link Down or Marginal Performance
  - Passive Components
    - Bad Link Connectivity (Cable/Connector)
  - Active Components
    - Bad Electronic Components/ECUs (PHY/Switch ASICs)
- Sporadic: Link Down or High BER
  - Passive Components
    - Bad Link Connectivity (Loose Connections)
    - Bad Link Shielding (EM Interference)

Self-Diagnosis
Persistent Link Failures or Marginality

- Persistent network connectivity failures per every Ethernet link in the vehicle are detected at vehicle startup upon request.
- SmartPHY provides Network Healthiness Metric (NHM) consisting of the following three measures initiated by a Central Diagnostic Unit (CDU)
  - Check Channel Quality (IL, RL, etc.)
  - Check Link Continuity (Signal Integrity)
  - Check Link Quality Metric (Link-up Time, BER, SNR Margin)
  - Check Electro-Magnetic Vulnerability (Shielding Effectiveness)

Self-Diagnostic at Startup
- Channel Quality Check

- Channel Quality Check:
  - The CDU sets a PHY as transmit only and another in receive only mode
  - The transmitter PHY transmit two tones with predefined frequencies and amplitudes
    - A low-frequency tone (e.g. at 1/10th the signaling Nyquist frequency)
    - A high-frequency tone (e.g. at the signaling Nyquist frequency)
  - The receiver PHY receives the two tones, and uses the magnitude of the two tones to calculates the link IL
  - The receiver PHY compares the calculated IL and sends it to the CDU
  - CDU evaluates the IL to determine the link IL pass/fail to determine

Self-Diagnostic at Startup - Link Continuity Check

- Check Link Signal Integrity
  - The CDU sets first PHY of every link in transmit only mode and second PHY in receive only
  - The first PHY uses time domain reflectometry (TDR) to evaluate signal integrity for all link points
    - The latency and magnitude of each TDR echo signal determines the location and magnitude of any discontinuity in the link for the first PHY
  - Next step, the first PHY is set in receive only mode and second PHY in transmit only mode, and the above steps are repeated
  - The link discontinuities information (locations and magnitudes) of both PHYs in every link is communicated to CDU
  - The CDU evaluates every link discontinuities information (individually & collectively) to determine link pass/fail

Self-Diagnostic at Startup - Link Quality Metric

- Check Link-up Time, BER, SNR Margin
  - This step is activated if the link passes the first two quality steps:
  - CDU initiates every link to start at-speed data traffic
  - Once the link is established
    - The **Link-up time, BER, SNR information** per link are sent regularly to CDU
    - CDU analyzes the information to calculate a ***Link Quality Metric (LQM)***
      - CDU uses LQM with different thresholds per link to flag Pass/Fail/Warning
        - For less critical links (e.g. Telematics traffic), the specs can be more relaxed
        - For critical link (E.g. ADAS traffic), the requirements are much more strict
  - LQM provides a wide coverage of the whole link end-to-end, including the quality of the active link components such as ECUs

Self-Diagnostic at Startup - Electro-Magnetic Vulnerability

- Check Electro-Magnetic Vulnerability
  - This test takes advantage of the reciprocity nature of electrical channel

  ➔ Bad link shielding results in higher EM emission as much as higher EM Vulnerability
  - The CDU activates the PHYs of each link, one link at a time, to transmit a clock signal (1010 sequence) at the signaling Nyquist frequency
  - Dedicated antennas, tuned to the Nyquist frequencies of the installed links, measure the EM emission level from each active link and send to CDU
  - Links with emission higher than its expected level are flagged as faulty
    - The extent of the fault can be determined by level of the emission
  - This diagnostic process increases the vehicle start-up time, but number of techniques can be used to minimize it
    - Example: Links with different Nyquist frequencies can be activated and measured simultaneously to save the diagnostic time

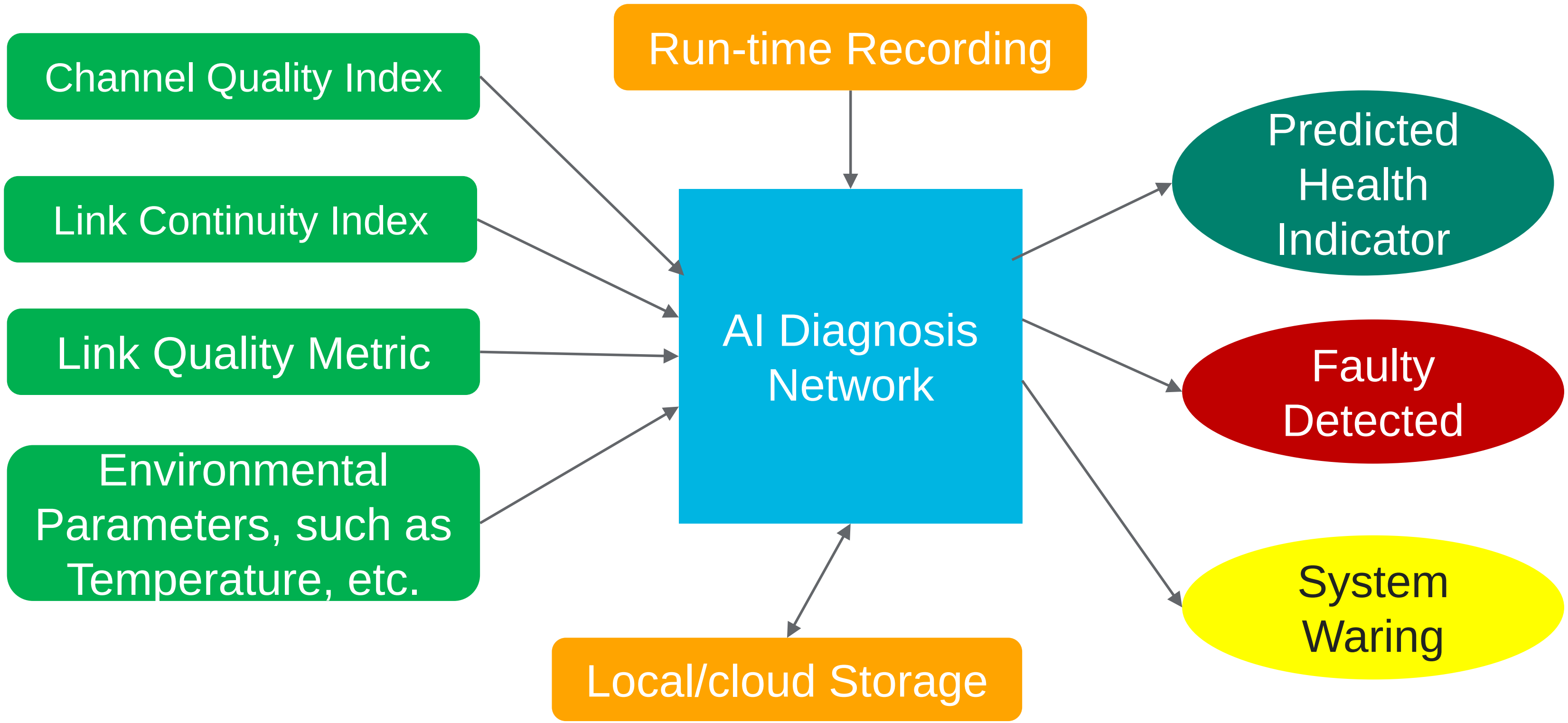
Self-Diagnosis
Sporadic Link Failures or Marginality

- Sporadic network connectivity failures or marginalities in the vehicle Ethernet network may not always be detectable at vehicle startup
- Two main causes for sporadic failures
  - Damaged or improper link shielding leading to high RF ingress noise
    - Shield removed on section of cable. Shield bad connection to ground
  - Vibrations, caused by Vehicle movement, affecting connections signal integrity
    - Loose connectors/sockets. Damaged solder balls
- Self-diagnosis process by CDU
  - CDU continuously monitors the LQM for every network link
  - Links that fail their target LQM more than expected are flagged as faulty
  - There will be no downtime drawback in this diagnostic, but will be some infrequenct increase in the IVN traffic and storage space

Predicting IVN Healthiness

- The ability to predict potential failure in the vehicle is often required to achieve high-level safety goals and provides a significant economic benefit.
- Prediction of network healthiness requires historical NHM data of the entire IVN.
- Prediction of the individual channels and further expanding to the whole network is possible with today’s advanced data processing technologies such as Artificial Intelligence.

Predicting IVN Healthiness



Summary

- SmartPHY provides Network Healthiness Metric (NHM) data of individual IVN links.
- CDU initiates, collects, and stores NHM data of the entire IVN.
- Self-diagnosis can provide real-time healthiness of the network.
- With advanced big data processing technology, effective prediction of network healthiness is possible.
- Prediction of potential failure in the vehicle assists in achieving higher-level safety goals and provides a significant economic benefit.

Q&A

MARVELL™

Essential technology, done right™