DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION INDIA

accellera SYSTEMS INITIATIVE™

An Overview of Ethernet 10Base-T1S in Automotive SoC and its Verification

DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION INDIA

accellera SYSTEMS INITIATIVE™

Bipul Halder
Principal Engineer
STMicroelectronics Pvt. Ltd.

Jagtar Singh
Member of Technical Staff
STMicroelectronics Pvt. Ltd.

Sahana S
Technical Leader
STMicroelectronics Pvt. Ltd.

Pushpal Nautiyal
Sr. Application Engineering
Synopsys

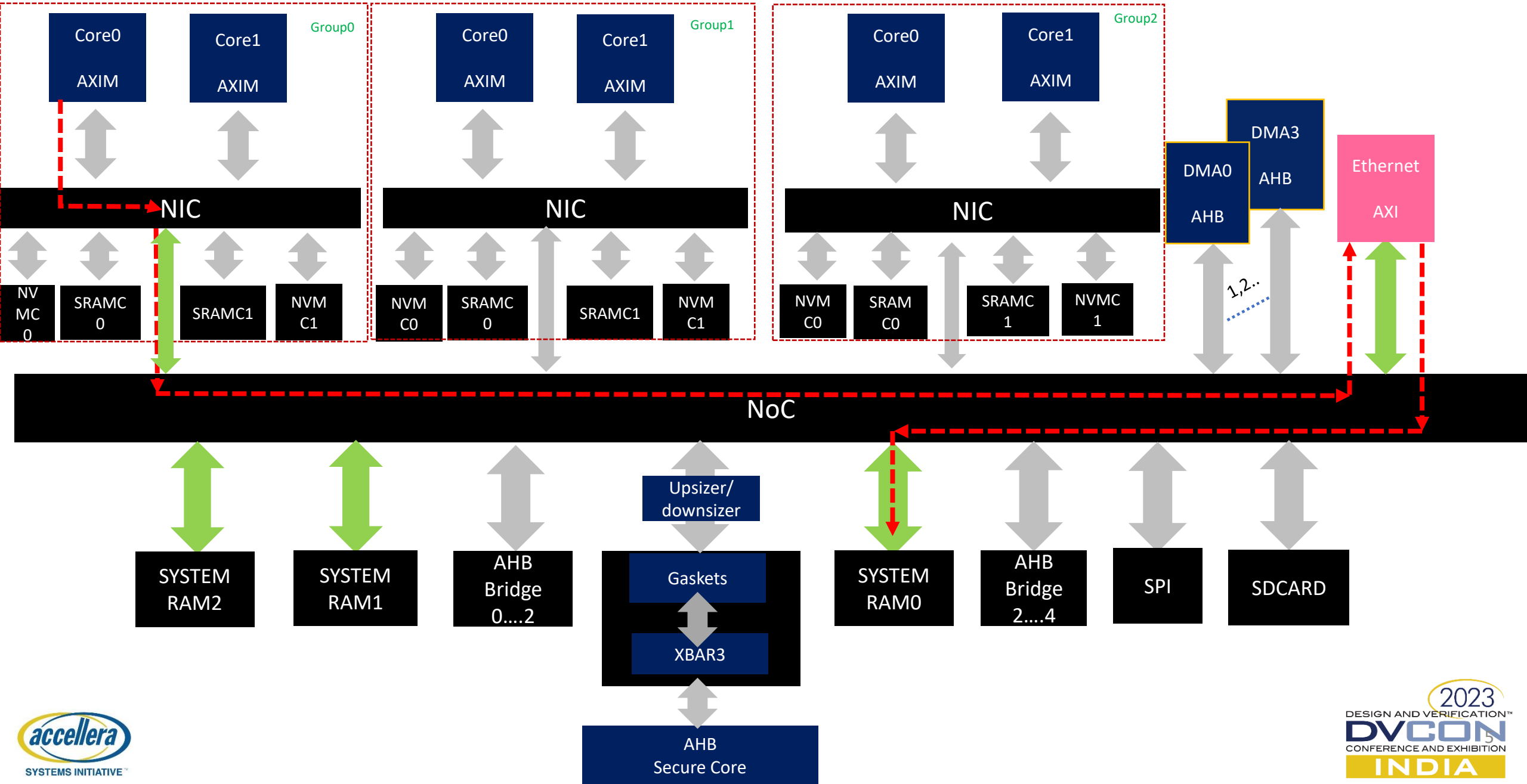
Gaurav Chugh
Senior Manager
Synopsys

Agenda

- # Automotive SoC
- # Ethernet feature set
- # 10Base-T1S Basics
- # 10Base-T1S over Legacy network
- # Verification Challenges at SoC level
- # Mitigating Verification Challenges with Synopsys VIP

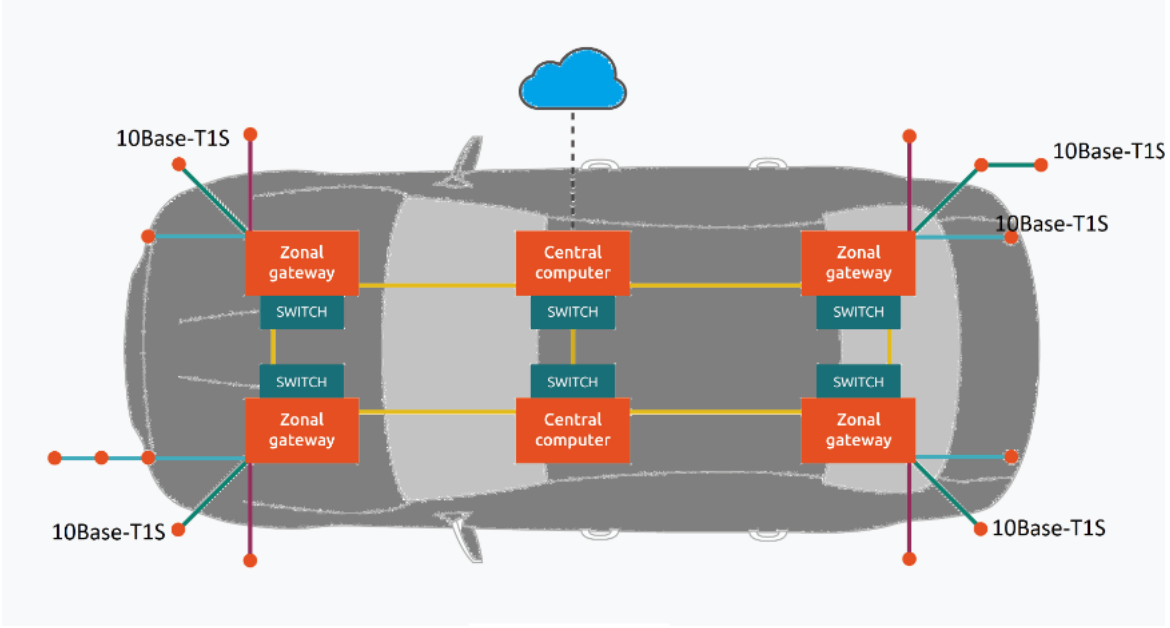
Automotive SoC

Typical Automotive SoC Block Diagram



Unique Aspects of Automotive

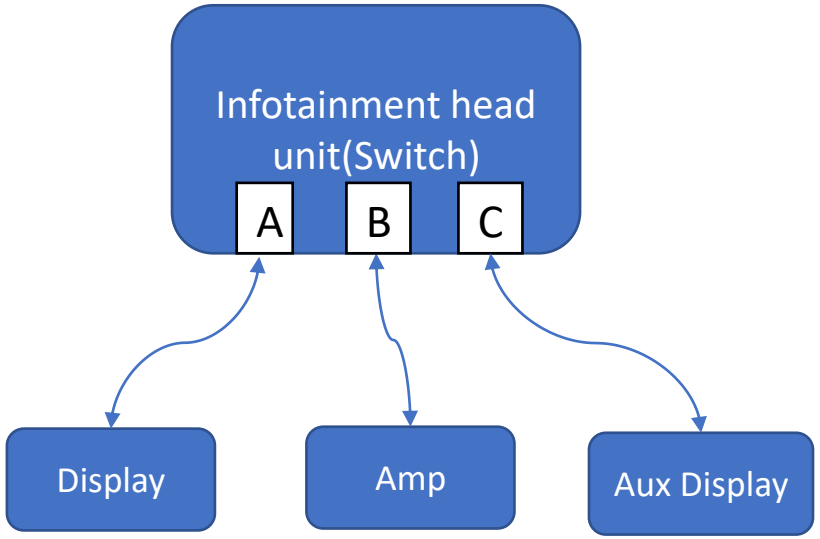
- Latest advancement in automotive industry need unified mode of communication which reduce wire length and weight in vehicle network
- Need transition to zonal architecture from Domain architecture
- Require higher bandwidth communication between ADAS(Advanced Driver Assistance Systems), infotainment systems, connected services and other ECUs(Electronic Control Units)
- Reduce the weight of the vehicle , which has a direct impact on vehicle range.
- Application with Deterministic operation within car



Ethernet Feature Set

Salient features of Automotive Ethernet

- What is automotive ethernet
  - Automotive Ethernet is a physical network that is used to connect components within a car using a wired network
- Some of the features of Automotive Ethernet are
  - Switched network
  - Automotive specific Ethernet Standards
  - Cost efficient
  - Networking topologies
  - Power can be delivered over ethernet cables
  - Deterministic and real time communication
- Why ethernet is essential for automotive
  - Flexible network, allowing easy reconfigurations
  - Provides significantly higher data rates compared to traditional communication protocols
  - Incorporate mechanism for deterministic and real time communication
  - incorporates robust security features such as authentication, encryption and secure communication protocols



Automotive Ethernet over Standard Ethernet

Differentiator	Standard Ethernet	Automotive Ethernet
Data rate	100Mbps to 400Gbps	10Mbps to 10Gbps
Length	Depends on the data rate 100m to 2km	15m
Connector	RJ45	Not defined
Cable	Coax to fiber optic depending on the speed	Copper, a single twisted pair with bi-directional data

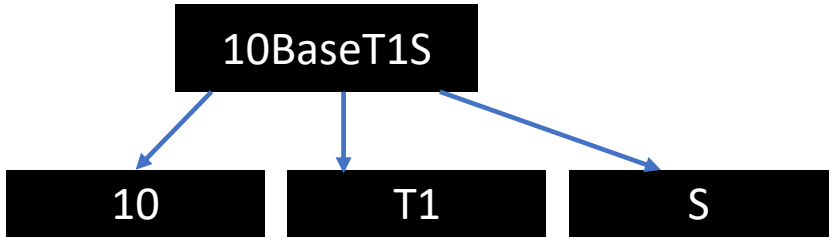
Automotive Ethernet Types

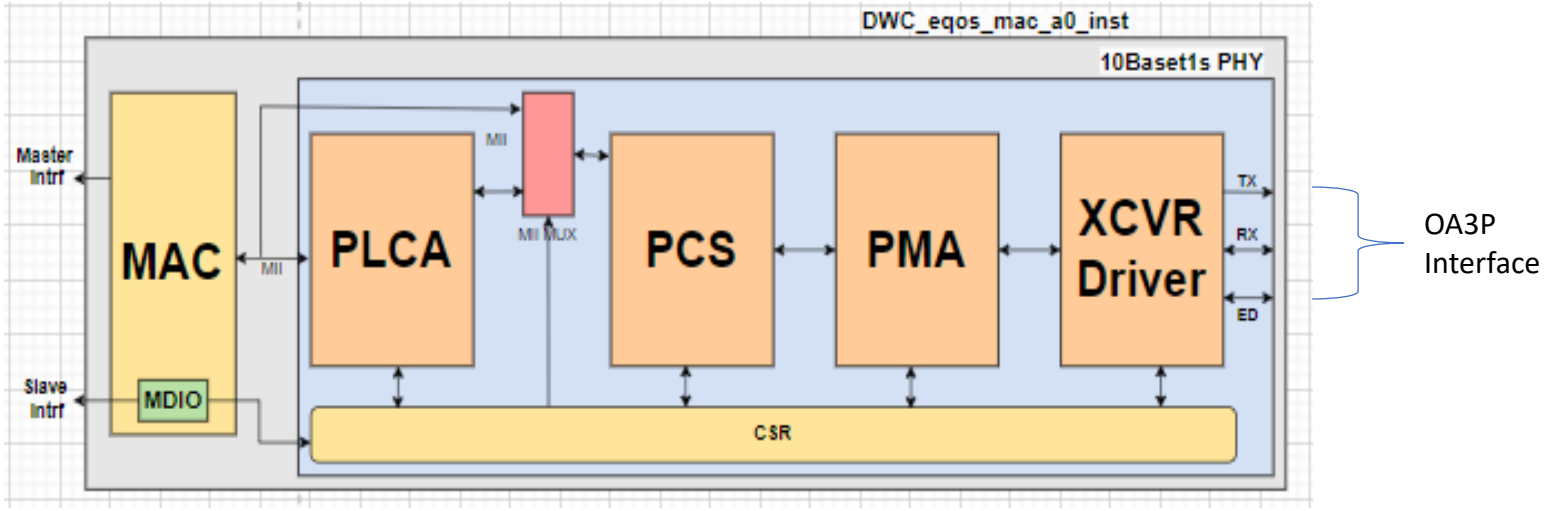
Name	Standard	Speed(M bit/Sec)
100BASE-T1	802.3bw	100
1000Base-T1	802.3bp	1000
10Base-T1S	802.3cg	10
2.5GBase-T1	802.3ch	2500
5GBase-T1	802.3ch	5000
10GBase-T1	802.3ch	10,000

10Base-T1S Protocol

10Base-T1S Basics

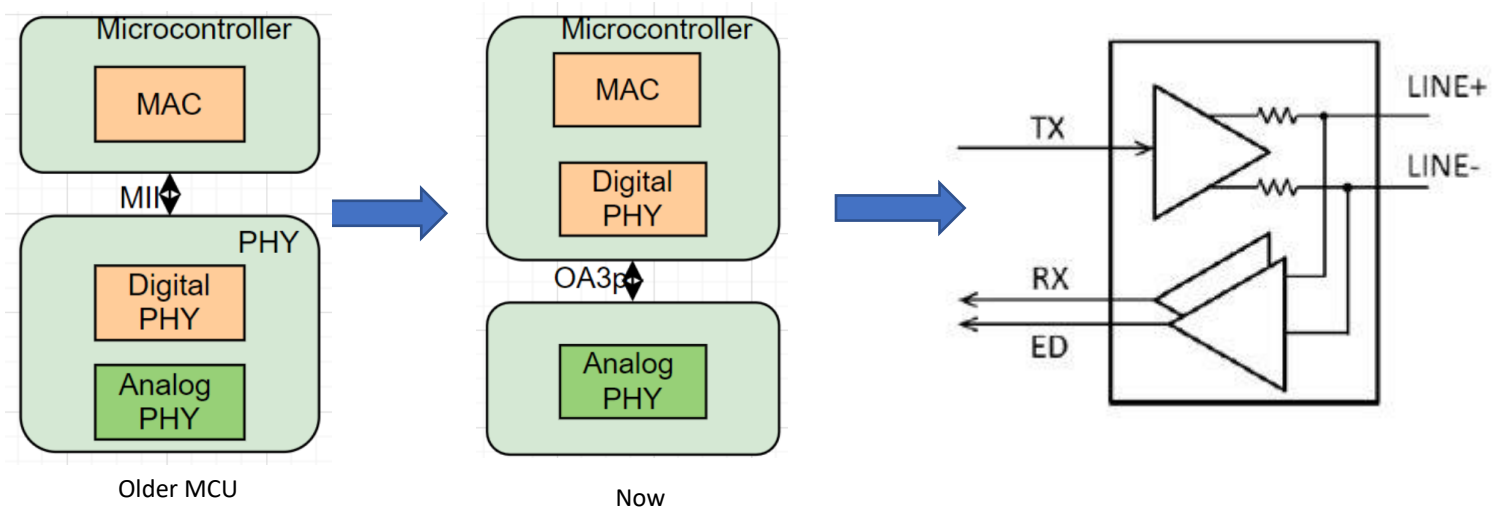
- Single Twisted Pair copper cabling similar to CAN-FD, Flexray
- Uses Physical Layer Collision Avoidance Method
- Bus access method is deterministic unlike CAN/CAN-FD
- At least 8 nodes 25 meters in reach
- Support PoDL(Power over Data Lines)
- 12.5 MBaud





Why Open alliance 3 pin 10Base-T1S

- Die Size reduces Significantly
- Low Form Factor
- Significantly less power consumption

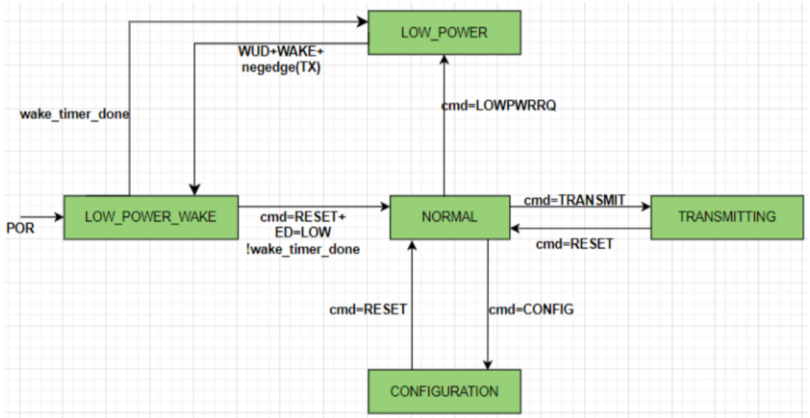


Older MCU

Now

10Base-T1S Functional Modes

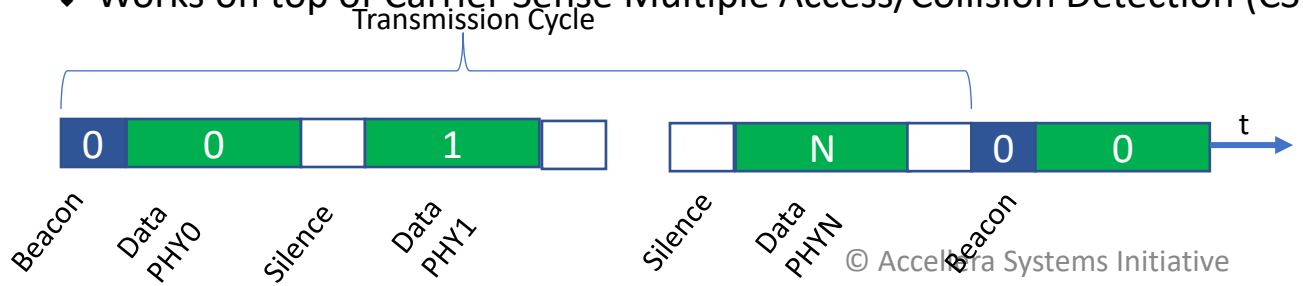
- Mentioned few Important Features verified with Synopsys VIP where IP is used as always HOST:
  - Full duplex
  - Half duplex
  - Half duplex Multidrop mode
  - Config mode
  - Low power mode



Transceiver Functional State Diagram

PLCA- Differentiating features of 10BaseT1S

- Goals
  - ❖ Full bandwidth utilization
  - ❖ Reduce latency
  - ❖ Quality of service(QOS)
- Principal
  - ❖ Avoid physical collision on the medium by organizing the media access
    - Called Physical Layer Collision Avoidance (PLCA)
- How it is done
  - ❖ Only the PHY that owns a transmit opportunity is allowed to send data
  - ❖ Transmit opportunities are given in a round robin manner
  - ❖ A new cycle of transmit opportunities is started when the master node sends a BEACON
  - ❖ Works on top of Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

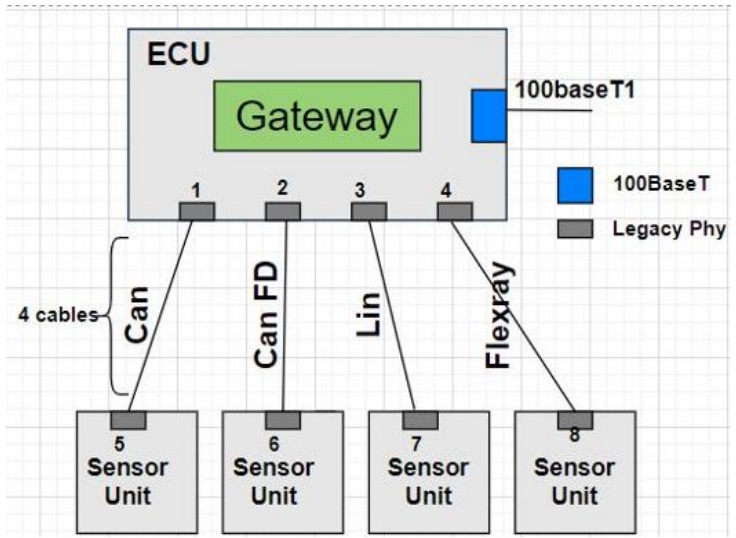


10Base-T1S over Legacy Network

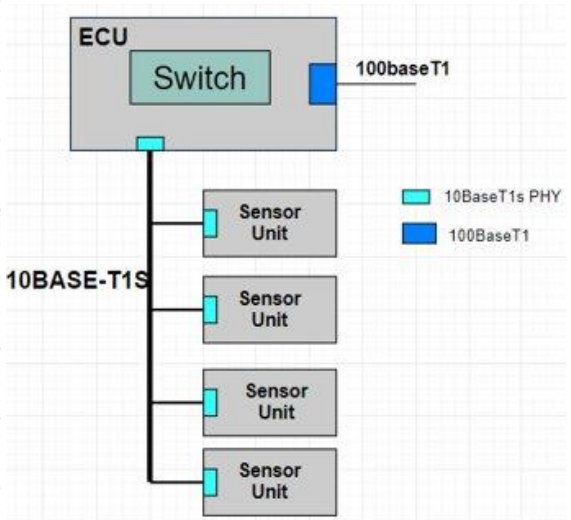
Legacy network vs10base-T1S network

Motivation & goals for 10Base-T1S:

- Provide an Ethernet based solution similar in cost to legacy networks(CAN-FD, LIN, Flexray)
- Simplifies network design.
- Reduce dependency on gateways
- BUS/Multi-drop architecture provides wiring cost benefits and reduces PHY count
- An alternative to 100Base-T1 for ECUs where 100BASE-T1 is not cost and energy efficient
- Offer optional PoDL support(Power over Data Lines) to further reduce complexity and cost
- A combination of 10Base-T1S and other Automotive Ethernet protocols allows a single software framework throughout the vehicle for all speed ranges



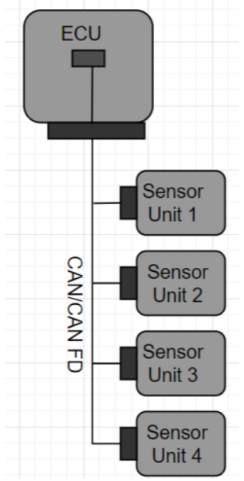
Legacy Car communication network



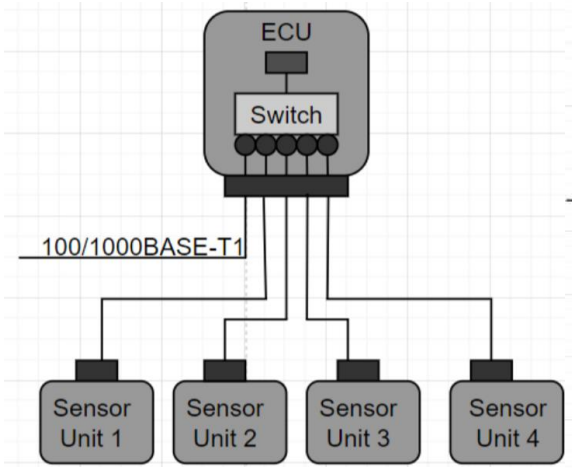
Now! Using 10BaseT

(1/2)

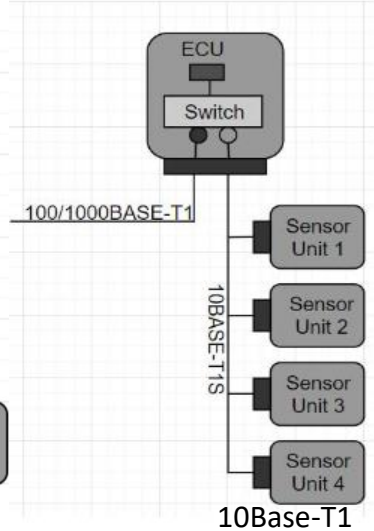
Legacy network vs10base-T1S network



CAN/CANFD



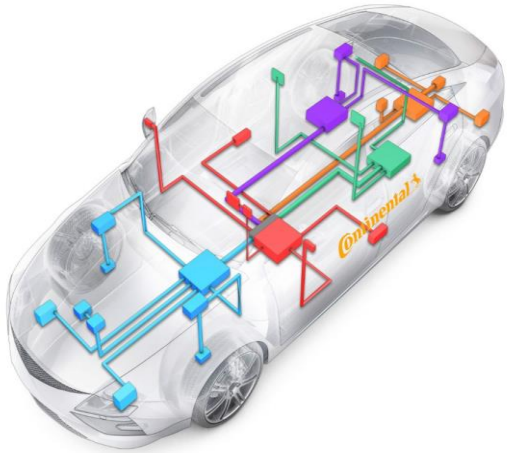
100/1000Base-T1



10Base-T1

Feature	CAN/CANFD	100/1000Base-T1	10BaseT1-S	Advantages of 10Base-T1S
# of PHYs/total Connectors	5	8	5	Fewer PHYs needed
# of Connectors on ECU	1	4	1	Fewer connectors and less connector space needed on ECU
Cabling	1bus line	4 Cables	1 bus line	Less cabling, extendibility, scalability
Bandwidth	<=10Mbps	>=100Mbps	10Mbps	More bandwidth than CAN
Ethernet Based network	No Seamless integration into overall	Yes	Yes	Seamless integration into overall Ethernet architecture

10Base-T1S : Application Domain



❖ Automotive Network :

- 10M Base T1S Network provide reliable communication channel for connecting to various electronic control units (ECU's) and sensors within the vehicle
- Replace legacy networks such as CAN , LIN , CAN-FD

❖ Industrial Automation :

- 10M Base T1S Network provide reliable communication for low bandwidth application (Applicable for connecting sensors, actuators in noisy environment)
- Replace EtherCAT , FieldBus , RS485

❖ Server Backplane Communication :

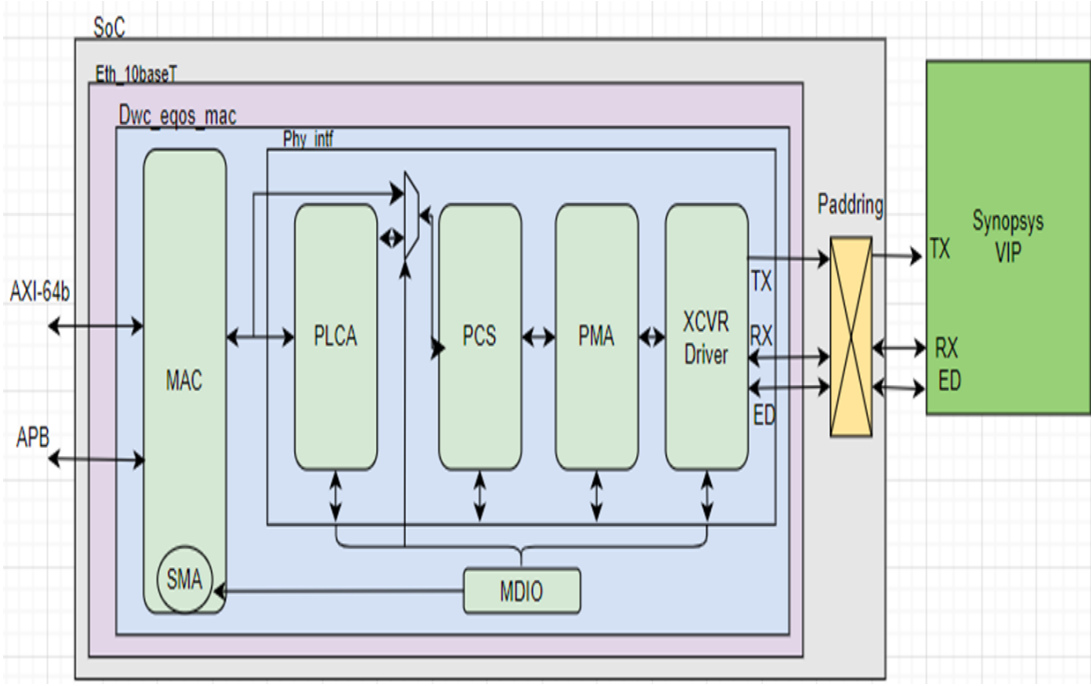
- 10M Base T1S Network help manage communication between processors, memory module and storage device where high data rates aren't needed
- Replaces several bus interface communication protocols like I2C,UART,SPI with a single 10M Base T1S network

Verification challenges at SoC

Challenges of 10BaseT verification at SoC level

Considering 10BaseT is relatively new in Ethernet Domain. It need careful environment planning and execution to ensure first time success and to minimize schedule duration.

- Domain knowledge: huge time and effort is needed to understand Complex communication protocol, consortium driven IP, Testbench and building Test environment
- SoC verification: Complex clock & reset architecture, multiple interfaces & data paths resulting huge number of scenarios at SoC
- Multiple platform like emulation to run jumbo frame transaction with max Burst, max outstanding to efficiently run simulations.
- Considering SoC cycle time, it become even more difficult to address complex scenarios to verify in simulation



Mitigating Verification Challenges with Synopsys VIP

MITIGATING VERIFICATION CHALLENGES

❖ Expediating the debug process for protocol related misbehavior

- Synopsys Ethernet VIP offers comprehensive debug techniques for faster triaging of issue
  - Ethernet VIP Debug Bus : Offers insights into following avenues
    - VIP's State Machine transitions
    - Data traversal across protocol layers

    (For Instance : Content of RS FEC Codeword/ 5bit symbols / 66b scrambled /unscrambled etc can be observed and compared if required)
    - Key protocol indicators

    For Instance : PCS link up/down , Frame accept / reject Collision occurrence etc
  - Comprehensive Simulation Transcript : Highlights following items
    - State machine transitions
    - Detailed protocol checker rule violation (if any)
    - Performance report
    - Frame transmission and reception statistics
    - Key protocol indicators (PCS link up/down , Frame accept / reject , Collision occurrence etc)

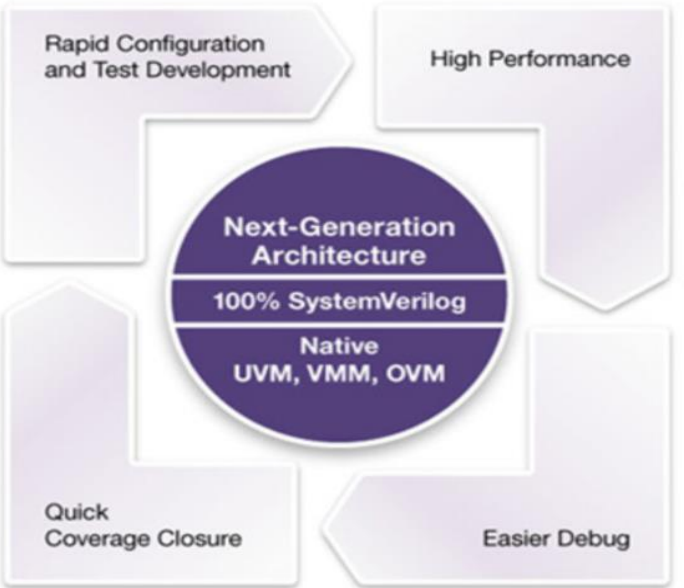
Debug Bus

MITIGATING VERIFICATION CHALLENGES

- **Availability of latest Draft especially Open Alliance Transceiver Draft 1.5 for 10M Base T1S verification :**
  - Synopsys domain experts are part of the working / task force /Consortium groups and are always abreast with latest evolution in the protocol domain
  - Constant drive from Synopsys Verification IP team to keep the products updated with the latest specifications/drafts available to ensure time to market for customer reduces manifold
  - Early availability for Transceiver Draft 1.5 in Ethernet VIP is a result of preempting the proposals submitted in the working group and kickstarting the development and verification cycle in nascent stages
  - Early availability for Transceiver Draft 1.5 in Ethernet VIP helped in the aligning ST's verification timeline with verification activity successfully completed in time bound manner

MITIGATING VERIFICATION CHALLENGES

- **Accelerating testbench development and authoring verification scenario's**
  - Synopsys Ethernet VIP offers Test Suite as a great value proposition for extensive and exhaustive set of IP verification
  - Salient features of Ethernet Test Suite VIP
  - Helps validate Protocol specifications of IP/Design block
  - Provided as unencrypted Source Code
  - Robust and Scalable Architecture allows verification at XMII/PCS/PMA layers
  - Tests can be easily extended and customized
  - Leverages VIP Built-in functional coverage and Protocol checks



MITIGATING VERIFICATION CHALLENGES

❖ Effortless VIP integration :

- Synopsys Ethernet VIP provides verification environment (Installation Examples) as part of the VIP deliverable to allow users to integrate RTL into existing verification environment .
- As part of the Installation example users can leverage pre-defined sequence library and sequences to initiate stimulus based on their requirements .
- Sequence library consists of constrained random stimulus highlighting generation of different Ethernet Frame types including error injection scenarios .
- If the users wish to integrate VIP into existing Verification environment, integration steps are quite easy and intuitive and very well documented in Ethernet VIP's User Guide .
- Synopsys Verification engineers work with the users to identify the appropriate verification topology, review integration steps and resolve any integration related issues

MITIGATING VERIFICATION CHALLENGES

- **Verification activity to have appropriate protocol expertise to ensure success for evolving standards**
  - Synopsys domain experts are part of the working / task force /Consortium groups and updated with latest evolving updates in the protocol .
  - These domain experts are involved in the development and verification cycle of the products including Verification IP

MITIGATING VERIFICATION CHALLENGES

❖ Key metrics for Verification Closure

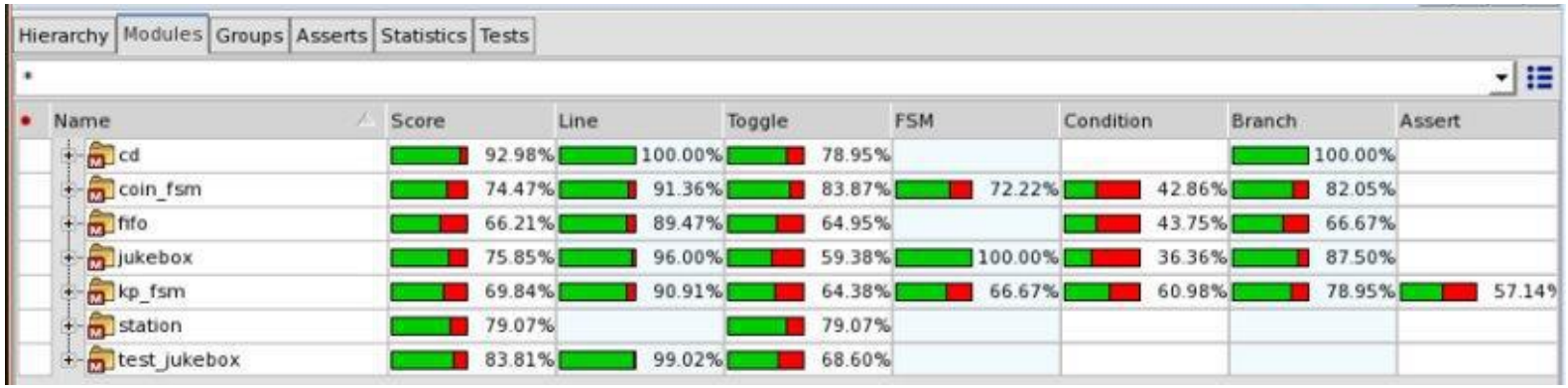
○ Coverage Closure : Code Coverage & Functional Coverage

- Code coverage : Highlights how much of the DUT code is exercised by verification tests during software validation ,
- Key Code coverage advantages :
  - Assurance of quality: Code coverage number assess completeness of verification process and highlights if critical aspects of code have been exercised or not and helps in detecting likelihood of bugs.
  - Stimulus generation effectiveness: In case some portion of the DUT isn't exercised at all, there is a need to add/edit the existing verification tests

MITIGATING VERIFICATION CHALLENGES

❖ **Key metrics for Verification Closure :**

- **Coverage Closure : Code Coverage**
  - Synopsys Verification tool Verdi showcase the code coverage numbers and highlight the portion of DUT code which is yet to be exercised



Name	Score	Line	Toggle	FSM	Condition	Branch	Assert
cd	92.98%	100.00%	78.95%			100.00%	
coin_fsm	74.47%	91.36%	83.87%	72.22%	42.86%	82.05%	
fifo	66.21%	89.47%	64.95%		43.75%	66.67%	
jukebox	75.85%	96.00%	59.38%	100.00%	36.36%	87.50%	
kp_fsm	69.84%	90.91%	64.38%	66.67%	60.98%	78.95%	57.14%
station	79.07%		79.07%				
test_jukebox	83.81%	99.02%	68.60%				

  - As part of code coverage closure, line, toggle and fsm coverage are tracked with the utmost priority.
  - Based on the portion of the code not exercised in line, toggle and fsm verification tests must be supplemented to ensure unexercised portion of the DUT code is hit.

MITIGATING VERIFICATION CHALLENGES

❖ **Key metrics for Verification Closure :**

- **Coverage Closure : Functional Coverage**
  - **Functional coverage : Augments the code coverage in verification closure.**
    - Key Functional coverage advantages :
      - Feature validation: Functional coverage targets key functionalities and features identified as critical for DUT verification.
      - Verification Completeness: All possible combinations defined in the DUT code and functional goals will be tracked

- Synopsys Ethernet VIP provides layered functional coverage model to allow verification engineers to focus on closing coverage gaps per protocol layer ie (MAC/ PCS/ PMA) thus ensuring no coverage holes

MITIGATING VERIFICATION CHALLENGES

❖ **Key metrics for Verification Closure :**

- **Coverage Closure : Functional Coverage**
  - Ethernet VIP provide verification planner where the functional coverage

  database generated in various simulation runs can be mapped with

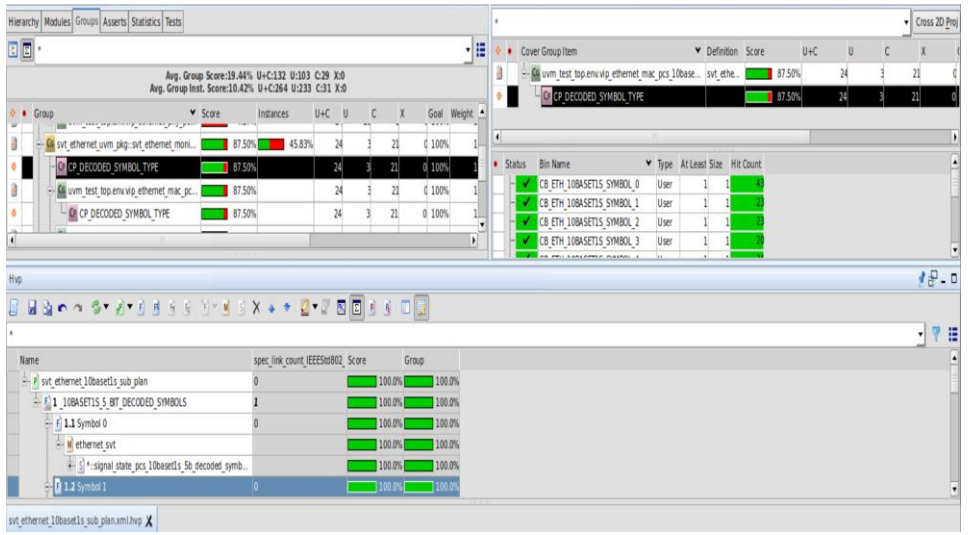
  protocol compliance clauses / sections / sub-sections.
    - For instance, for 10M BaseT1S simulations all the protocol

      clauses and their section / sub-sections such as

      Clause 146/ 147/ 148 will be defined in verification planner
  - Functional coverage numbers can be annotated to gauge how

  much functional coverage is exercising protocol clauses / sections

  sub-sections.

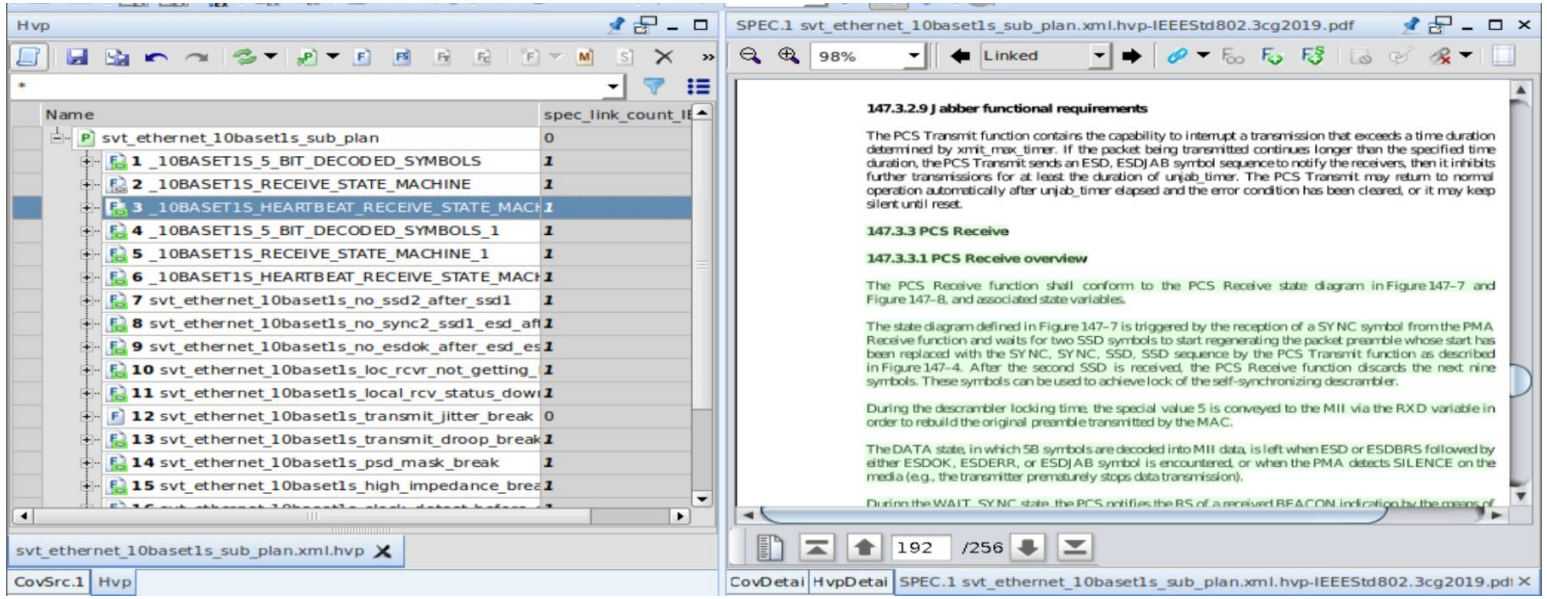


MITIGATING VERIFICATION CHALLENGES

- **Key metrics for Verification Closure : Specification Linking**

  - **Specification Linking : Maps Verification Plan with Protocol specifications**
    - Instills confidence in verification engineers : Reflection of how verification plan caters to all the relevant protocol clause/section/sub-section, thereby ensuring none of the critical portion is missed.
    - If the specification linking coverage numbers are 100%, it indicates that the verification planner is encompassing all the protocol clauses/sections/sub-sections

Ethernet VIP provides mapping of the verification plan with specific protocol clauses/sections/sub-sections.



Thank You