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Event Management in Automobile Network

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Abstract

The introduction of multiple networking technologies and protocols in automotive, starting from CAN in 1990 to TTP, FlexRay, Ethernet to date has given way to new modelling methodologies which are software based. In today's automotive, more than 100 ECU's exchange thousands of events to determine the diagnostics at a given point of time. The quality of the vehicle over time will be a function of these events and new concepts along with solutions in this area will be of great interest to automotive OEM's. In this paper we will see how these events are correlated. Having this correlation is a great asset to all stakeholders in the automotive industry. We will analyze the concept of event correlation and two different methods to implement event correlation in automobile platform with dedicated ECU for the purpose to be preferred method of implementation.

Keywords

Correlation, event types, events, root cause, vehicle.

INTRODUCTION

Electronics in automobile is no more optional, but essential evil. With the growth of electronics, programming code also grew by multi-million lines. The major break through was modular development using standards for portability and interoperability. With this evolved modelling tools and model development in the auto industry.

With the increased number of ECU's and corresponding code, diagnostics was always at the centre of development. Diagnostics module in the vehicle were getting advanced with the introduction of keyword protocol2000 [1], unified diagnostic services [2] and further use of XML to specify diagnostics function for suppliers.

Platforms like Adaptive autosar envision diagnostics to be provided as a service over the platform with multiple stake holders. Diagnostics over IP will be a future norm rather than exception as today.

For handling thousands of events generated, correlation will assist in identifying the root cause and resolve the issue in a timely manner. Without correlation, complexity of diagnostics tools will increase exponentially in the future. There can be two approaches to implement event correlation in automobile or vehicle networks. One is the central approach and the other is hierarchical. Central approach includes collecting event at a single edge node to apply correlation model and to implement this option implementation needs a single collector node for analysis in time t or have a multipath to collect events and use it along with other data. In short, one needs to create a single collector node in a separate ECU where all the events can be analysed in real time and then correlation applied as shown in Figure 1. This correlation set up can be configurable as per the requirements[3].

The other hierarchical approach involves correlation at each ECU as well as for the vehicle [4]. This will suit adaptive autosar using dynamic scheduling strategies.

EVENTS AND COORELATION

Autosar Network Components and Events

Autosar Network can generate multiple events for each ECU. Each ECU in turn can generate multiple events for its subsystems. But autosar Network and vehicle ultimately sends events related to pre-defined attribute at the fundamental level. Hence in the central approach, to conclude on a root cause it finally comes down aggregation of these attributes for total events at the given point of time. In the hierarchical model, specific model applies at every node at that point of time and only correlated event goes to the next level.

Event Correlation Model

Event correlation updates will be as below.

```
EventCorrelation_updating (Event e) {
If (Events are from the same module) {
Apply module_specific_correaltion model;
} else {
if (events are from different modules)
apply network-correlation model
} else if (multiple events from single module and multiple
events from multiple modules
{
segregate-events
apply specific model
}
update final-correlated-events;
}
```

In the event correlation, module specific correlation model, model needs to be based on event attributes defined. Events can be from single module or multiple modules. Events can also be combination of module and vehicle as a whole. Apart from these events could be related to transitions state. Transition state events could be specifically useful for correlation.

For the both centralized and hierarchical correlation, let E(t) be total events reaching event manager at time t and Ev(t) be events generated by automotive ethernet switch having n connections and Es(t) be service events from each ECU's connected to switch. Assuming automotive switch is down, flood of events is,

$E(t)=Ev(t)+n*Es(t)$

As indicated by E(t), it is the time that is most important factor[5] for correlation. This is a challenge as it is not GPS time, but system time or GPT or system component time [5] in other cases and needs to account for time zones. Additional challenge is requirements for run time environment [6] impacting the time t. In a large deployment of multiple vehicles communicating with each other via roadside devices or 5G network, central correlation assists in pointing to root cause, but operator's knowledge or knowledge database also plays a role. Additionally, when experimented with a simulated hardware in loop setup in the lab for hierarchical correlation using real events as well some simulated events, it is found that correlation is stronger with either time t being same for all these events or attributes being related with respect to time. The same was true for centralized correlation too, but accuracy was higher in hierarchical correlation. In hierarchical model it was found that event correlation was more accurate as both latency and delays were less and time closer to real. Also, for every correlation component in hierarchical model, the number of events to be handled were less with hierarchy. If at time t many devices report not reachable, correlation may point to specific ECU or switch down. This could be arrived at based on both topology and time. But for hierarchical correlation model, this was much faster. On the other hand if we have a event stating fan issue on certain module and after t+~t, we have high temperature from same module and then t+~t+^t, we have same module unreachable. Root cause can be identified to fan event based on duration or interval. Now again in hierarchical model, this is handled at module level itself rather than at network level and hence faster and efficient. Both these types will be inputs to the correlation model [7].

COMPONENTS

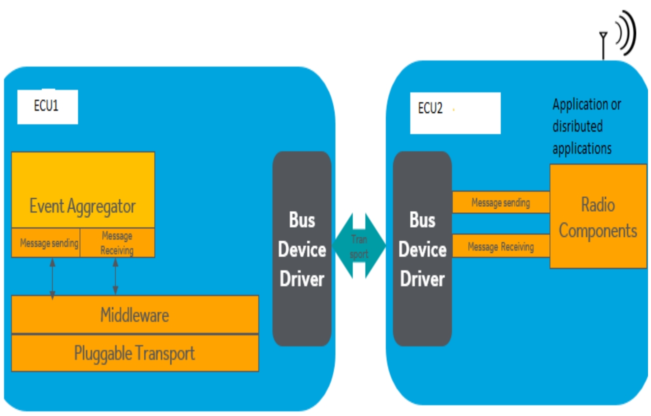

Figure 1. ECU's sending events to local dedicated Aggregator

ECU's send multiple events to event aggregator at the embedded control unit dedicated for this purpose. Rules or algorithms are applied by event aggregator and corrections are applied here or in the worst-case scenario when multiple aggregate events are a result, they are sent to centralized station/cloud via roadside devices or 5G for further analysis and operator action. If a single event is a result, a field person and user can be involved for correction at the vehicle level [8]. This architecture makes sure only when required, events are sent to operator either at field level or centralized level. Individual events are not sent to cloud or centralized monitoring unit or traffic sub center, but either resolved at the vehicle level itself or correlated event is sent to centralized control for assistance. Event correlation in this case is applied at local vehicle level depending on nature of events, relationships and rules or algorithms.

The other model has all the components sending events to centralized cloud and it does correlations at network level. But this approach will not work in congested urban areas. In case of a network issue, this approach may flood the network with multiple component events (autosar infra component events, BSP components events, ..) causing packet delays. . If many such applications try to send events to centralized server on the network, it will flood the network and in the worst-case correlation may not happen as many events may have been lost due to CPU and channel bandwidth issues. These scenarios can be better handled at the device level itself.

Figure 2 shows when event correlation is done in each ECU, since many other applications run on the same ECU, certain application get into high CPU utilization mode with no cycles left to send the events further.

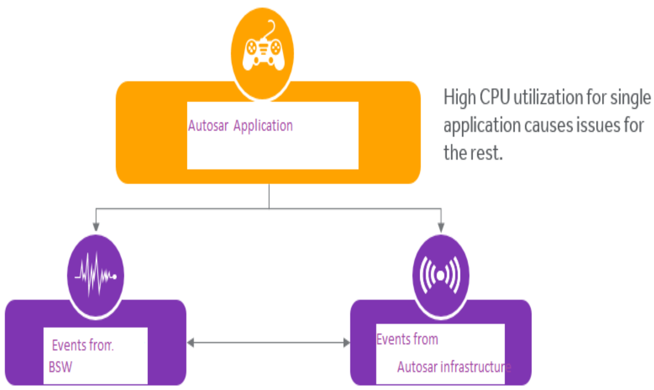

Figure 2. Event Management and correlation at each ECU

The auto manufacturer are not guided by the rules unless they follow standards, and even when they follow standards implementers are free to choose the protocols they wish to follow to send events to cloud or management station or traffic sub center. The result is that one vendor device may not be able to send events to another vendor device though they all can send events to management station or Traffic subcenter as generally they are designed to understand different protocols. In this context combination of both approaches becomes essential.

Collective events can show the deficiencies of the topology, device features and components too. In the real autosar network knowing this is important to take corrective actions and will be key to solving many issues as maintenance availability may be limited in most remote areas.

Auto devices are resource constraint. Hence it is essential that events be selectively configured [9] or dynamically chosen based on the resource and bandwidth availability. During prototype implementation it was found that dynamically chosen events where physical interfaces directly communicated with transport skipping kernal calls were the most efficient.

EVENT AND TRAFFIC MANAGEMENT

It becomes prerequisite to check availability of ports [10], virtual function bus, autosar channels and transmitting slots before transmitting the event. The functionality of the vehicle should not be impacted during the event management and it should aid in both the performance and functionality. QOS based scheduling becomes important to send these events and event aggregator needs to be designed to interface with QOS modules on allotted ECU.

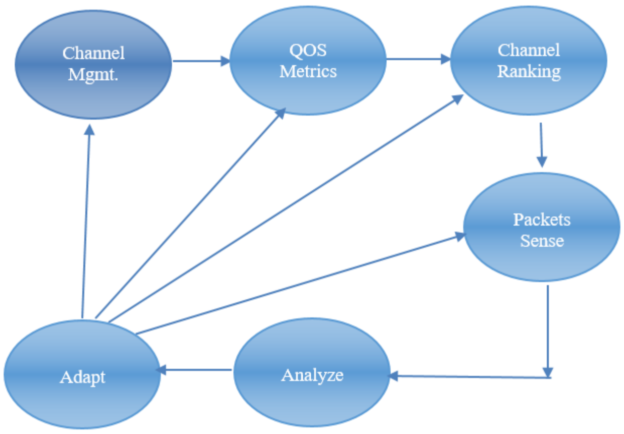

Figure 3. Virtual Function autosar channel Mgmt

ARCHITECTURE

What are the components of event correlation? Key to event co-relation is event aggregator component. Event aggregator component works in real time, Events are received in real time and based on time stamp of event it is acted upon. Then correlation can be applied. Figure 3 shows event correlation for one such model where aggregated events are correlated. It takes help of designed rules, relationship between different network components, database, and algorithms to act on. In some cases, algorithms are eliminated due to the real time nature of events. All sub domain managers may forward events to this aggregator and aggregator will act with correlation engine to find the root cause and then forward the event to central manager or cloud or traffic sub center.

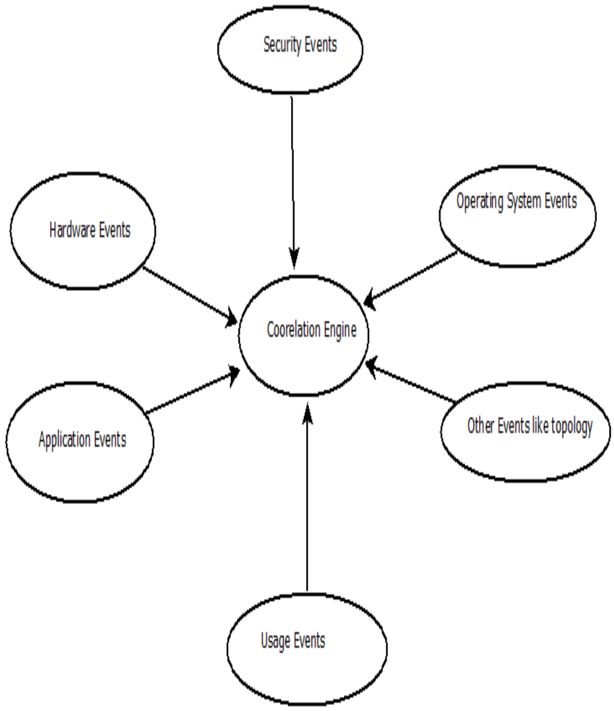

Figure 4. Simple sample model for aggregated events to correlation engine implementing algos

For the other hierarchical model, system components and their relationship play a more vital role. How many processors are? How many peripherals are? How are they connected? Memory, disk [11] etc.?

EVENT CORRELATION WITH AI

Autosar network needs to be functional in the most demanding situation where the bandwidth, range, and mobility all three needs to be balanced. Implementation with the below considerations shows a vast improvement in these situations when they are correlated with other performance parameters. If this correlation is done in cloud or traffic sub centre, it can also consider earlier events and network traffic from the database for correlation.

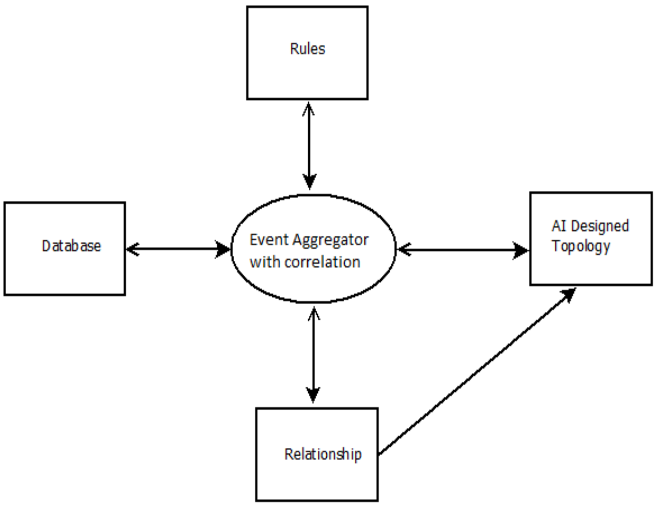

Figure 5. Event Aggregator for AI designed correlation model

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Relationships are important for correlation. One such an important, but static relationship is the hardware [12]. Models and algorithm when fed with this relationship can determine the events correlation to find the underlying root cause [13].

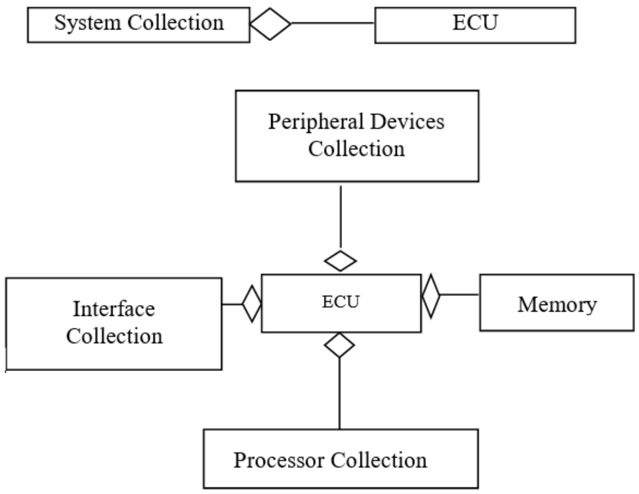

Figure 6. Sample Component relationship for correlation for a single autosar module.

RESULTS

For three vehicles and if we gradually increase the data traffic in a controlled environment, simulation shows that events get dropped over time if aggregation is done further from the event generating ECU.

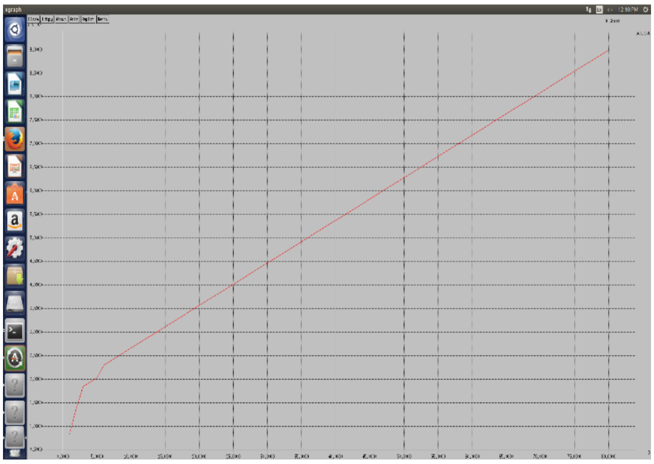

Figure 7. Events dropped with time.

Event drops decrease if correlation is done in the same vehicle for all ECU events and as correlation model is refined, network events are minimized showing lesser events drop for the same data traffic and high probability of pointing to correct root cause at central station or cloud or traffic sub center demonstrating the efficient design.

CONCLUSION

Correlations in automobile networks show that closer we are to delta (time t) for all events i.e., real time - correlation points to the root cause even when we take mobility, range, and bandwidth into consideration. Further we go from this delta, it becomes difficult to point to real or root cause. When AI and analytics is used for correlation, it helps in pointing to root cause in many cases. Best is hierarchical correlation where it is possible to distribute event correlation in vehicle, but needs to add device manager for every ECU to get closer to this delta. But hierarchical correlation is also challenging with limitations of memory, CPU and software queues in field when future dynamic requirements of autosar is considered. It is suggested to have the requirements and database from the field to get to the best possible modelling to utilize these approaches in a practical scenario.

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