# Design and Safety Verification for Vehicle Networks

Debasis Das(✉) and Harsha Vasudev

Department of CS&IS, BITS Pilani K.K. Birla Goa Campus,
Zuarinagar 403726, Goa, India
{debasisd,p2016411}@goa.bits-pilani.ac.in

**Abstract.** There is a serious mismatch between the growing traffic volume and the availability of resources to support the traffic. Some of the important reasons for this mismatch are the rapid development of our economy, increased affordability of our society, multiple vehicles per family, and so on. We believe that the mismatch will continue to grow and adversely affect our traffic infrastructure unless efficient traffic management solutions that include system integration, design, prediction, safety verification, validation, and security are developed and deployed. Security has appeared as an important issue for Intelligent Transportation Systems (ITS). Some security threats become more challenging task with the emergence of Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Roadside (V2R) communication in vehicular networks. Addressing the security issues in smart vehicular communication systems requires new effective and efficient algorithm that encompass considerations of new security techniques, safety things, communication related resource limitations, and other related new performance metrics. In this paper, we recommend a unified framework and new metrics that combines integrated modelling, system integration and optimization, official certification and validation, and automatic synthesis approaches for analysing the security and safety of ITS and booming out design space investigation of both in-vehicle electronic control systems and vehicle-to-vehicle communications. This integrated framework will facilitated the system integration and optimization and enable validation of various design the new metrics for vehicular networks such as timing, direction, reliability, speed, security and performance.

**Keywords:** Vehicular networks · V2V · V2I · Safety verification

## 1 Introduction

The Intelligent Transportation Systems (ITS) [1] for smart cities holds promise for a sustainable, effective, cost effective and a balanced solution for Vehicles at road, highway and intersection [2]. ITS is basically the use of computer and communications technologies coming in support of the transportation problems. They enable assembling of data or intelligence and then give timely response


N. Kumar and A. Thakre (Eds.): UBICNET 2017, LNICST 218, pp. 220–232, 2018.
https://doi.org/10.1007/978-3-319-73423-1_20

to traffic supervisors and road-users. The objective of vehicular networks [3,4] is to provide an efficient, effective, fast and safe interchange of safety related information such as obstacle warnings or lane change notices or the communication with road side units for the purpose of traffic information and infotainment applications is based on the smart transportation.

As vehicles can easily be equipped with positioning capabilities and wireless transceivers [5,6], they provide a suitable platform for geographic routing protocols [7,8]. Primary application areas of these technologies are vehicular networks, society application and military communications. A real-world implementation of an efficient communication and routing protocol was used for inter-vehicle communication in Vehicular Ad hoc Networks (VANETs) [17,18,20]. In recent years, the improvement of intelligent transportation for next generation smart city communication has achieved great leaps in the field of information and communication technology. Various applications have been developed to improve vehicle safety (e.g., collision avoidance, emergency warning message, weather condition warning, traffic condition warning and road condition warning) and traffic efficiency (e.g., speed management and cooperative navigation). Most of all applications are constructed through vehicular communication networks [18–20], where vehicles transmit and receive security acute data such as speed, acceleration and distance, as well as general information such as traffic and weather, so that drivers or vehicles themselves may respond to various situations in a timely manner.

The architecture of the smart vehicle for smart city communication has became more heterogeneous. The different types of sensors such as Light Detection And Ranging Light (LIDAR), radar, Global Positioning System (GPS), smart phone and cameras are used to collect the environmental information and fast and efficient computation units includes the high speed processors, Graphics Processing Units (GPUs), and Field Programmable Gate Arrays (FPGAs) are used to process by the sensors (i.e., Internal Sensors and External Sensors) and make driving decisions based on the collected data from real environment [3]. The sensors, high speed computation units (i.e., processors) and actuators are connected to a heterogeneous bus systems where the multiple buses are such as Controller Area Network (CAN), FlexRay, Local Interconnect Network (LIN) and Ethernet connected through the gateways [13–15]. However, a large amount of highly complex data generated by the intelligent sensors needs to be processed at real time, and the workload could vary significantly due to the changing environment while driving because vehicular networks means highly dynamic nature of mobile nodes and constantly changing the environments.

A hybrid framework that integrates the hybrid modelling, system integration and optimization, official certification, validation and automatic production techniques for analysing the security and safety of smart transportation and booming out the design space investigation of both intra vehicle electronic control systems and inter vehicle communications for smart city communications. Some examples of intelligent transportation for next generation smart communication include innovative traffic management systems, innovative traveller information systems, innovative vehicle control systems, innovative electronic toll collection systems, innovative public transportation systems, etc.

The rest of the paper is organized as follows. Section 2 describes the summary of the Related Works. Section 3 explains the proposed Model for Smart Communications for Smart Cities. Section 4 illustrates the Solutions for Next Generation Automotive/Semi Automotive Systems. Section 5 gives the New Parameter for Autonomous Driving. Section 6 gives the Proposed Framework for Next Generation Automotive/Semi Automotive Systems. Section 7 illustrates the Limitations and Possible Solutions. Finally we have presented the Conclusion in the Sect. 8.

## 2 Related Work

In the literature review, several existing automated design space exploration techniques have been proposed to address the system integration challenge for autonomous, semi-autonomous and human driven vehicle for smart cities. Zheng [1] proposed an architecture modelling and exploration outline for assessing various software and hardware architecture possibilities. The proposed system framework allows system integration and optimization. They have also mentioned that this system allows the authentication of different design parameters such as security, reliability, timing etc. The main challenges mentioned are prediction, verification, validation, system integration etc. Zheng [3] proposed a unified framework that combines hybrid modelling, formal verification, and automated creation methods for analysing the security and safety of transportation systems. They have mentioned that all modern vehicles, more precisely the most safety acute components are attacked now a days, so in order to address these issues some broad approaches like, resource constraints, safety properties, security mechanisms and related some system metrics should be considered.

In [5], Schatz et al. proposed a technique of using constraint-based formulation for automotive optimal software and hardware design, under the requirements of ISO26262 standard for automotive safety. In [6], Oetjens discuss the advantages and research challenges of virtual prototypes that can virtually mix motorized software and hardware and do design space examination and system certification. In [7], Eberl further combine firmware related functionalities like diagnostic tests into a holistic design space examination structure for motorized electrical/electronic (E/E) design for automotive networks. In [8], the Yu propose a model-based formal structure for motorised control software in terms of challenges interoperability. In recent work, the authors in [9] propose an early model-based design and verification framework for automotive control system software. In [21], Petrenko introduces the model based testing technique and envision the future test generation tools with "tester-in-the- loop" support. In [22], Krishna introduces a formal model for analysis the automotive feature production lines that is capable of capturing variability and real-time behaviour. In the literature, there are a lot of work based on enhancing automotive software control reliability [12]. In [1], the authors proposed a structure to check and verify temporary errors for motorised security acute applications. In [3], the authors study and discuss the faults during the start up and operation of a FlexRay network, and propose a bus guardian.

## 3 Proposed Model for Smart Communications for Smart Cities

Autonomous/semi-autonomous/human driven vehicles have the ability to percept the environment and make driving decisions without human intervention or partially or fully human intervention for smart city communication. The basic methods of a typical autonomous/semi-autonomous/human driven vehicle include Awareness (i.e., perception), efficient route planning, innovative behavioral executive and innovative speed control. The awareness method is to collect and fuse internal and external information from various sensors (i.e., internal and external sensors) and perform works such as efficient obstacle detection, road/highway/intersection shape estimation and localization (locate the relative position of the vehicle to the road using GPS). The efficient route planning method is to generate high level route to fulfill the travel mission while considering travel time, distance, speed, direction and traffic condition at road/highway/intersection. The behavioral executive methods is to decide driving behaviors such as lane change at simple highway, intersection behavior means direction changing and parking lot behavior, based on the traffic information and internal vehicle information from the awareness method, while following the navigation from the efficient route planning method. The speed/velocity control method is to physically execute the behavior generated from the behavioral executive method by controlling the actuators such as steering, acceleration and braking. Besides the basic functions, some systematic services may be needed including efficient jobs management, efficient and effective communication services for smart city communication, system configuration for smart vehicles, and fault/error handling for vehicular networks, etc. With the emerging vehicular network (e.g., the dedicated short range communications technology), Autonomous/semi-autonomous/human driven vehicles are able to communicate with each other through the V2V or V2R and exchange important information with the roadside units or other vehicle they are with in the range of the sender vehicles. This can further help the planning and control methods to make driving decisions and efficient communication for smart cities.

Traditional buses like CAN are reaching their boundaries as the increasing volume of data processed by Autonomous/semi-autonomous/human driven vehicles requires increasing bandwidth and scalability of the systems. Fully switched Ethernet is presented in the Autonomous/semi-autonomous/human driven domain to be a good candidate for Autonomous/semi-autonomous/human driven driving technologies.

## 4 Solutions for Next Generation Automotive/Semi Automotive Systems

The new movements of autonomous/semi-autonomous vehicles post challenges to the design of next generation fully automotive or semi automotive system integration, design, prediction, verification and validation to analysis and optimization of various design metrics such as reliability, security and performance (i.e., throughput, end-to-end delay, and fault tolerance). The fully automotive or semi automotive systems will be equipped large number of heterogeneous components such as sensors, GPS, actuators, buses, and computation units. The fully automotive or semi automotive system integration have to process a high traffic volume of data using intelligent algorithm for smart transportation.

### 4.1 Hybrid Systems for Autonomous/Semi-autonomous Vehicle

The Next Generation autonomous/semi-autonomous driving applications require large number of different useful units to run concurrently, while ensuring several timing and vehicular resource limitations to be met. In our propose hybrid architecture, each job inside the dissimilar functional component needs to finish execution within its deadline, and the end-to-end latency from sensor to actuator must not exceed certain threshold value.

### 4.2 Safety Verification and Validation for Smart Vehicle

Safety is considered as particularly significant in Next Generation Automotive/Semi Automotive System [16,17] design. To guarantee safety, the hybrid system should be unified and verified through a holistic structure that confirms proper operation and execution of the complex software units on a heterogeneous platform.

### 4.3 Analysis and Optimization of New Design Metrics

Analysis and optimization of new design metrics (e.g., timing, control performance, reliability, security, fault tolerance, throughput, end to end delay, and energy consumption) also post great challenges to fully automotive or semi automotive design process.

**Reliability.** Due to the non-stop scaling and lower power of integrated circuits, and the radiation from the environment, next-generation fully automotive or semi automotive systems are more prone to soft errors.

**Security.** Security Different types of sensors, GPS, actuators, the heterogeneous bus system and the incorporation of vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communication provide attackers with a large number of attack surfaces. In this work, we proposed a unified framework that combines hybrid modelling, formal verification, and automated synthesis techniques for analyzing the security and safety of transportation systems for smart cities.

**Energy Consumption.** In Vehicular Networks energy consumption is an important parameter for smart cities. Here, we developed an efficient and effective method to reduce the cost associated with automotive idling and some new technique to reduce an energy consumption of controllers through model-based design for automotive control systems and also reduce the stand-by power consumption.

# 5 New Parameter for Autonomous Driving

## 5.1 High Volume of Data

Autonomous/semi-autonomous vehicles need to accumulate and process large amount of data at real time. It is reported [1] in that Google's experimental autonomous vehicle generates 750 MB sensing data per second to be transferred through internal CAN buses and Design and Safety Verification for Vehicle Networks processed by various components. In the proposed system, it takes extra time for the insight unit to detect objects in the complex down-town area than on simple rural roads.

## 5.2 Dynamic Data Generation and Transmission

In the case of autonomous/semi-autonomous vehicle they dynamically generate and transmit the large amount of traffic data. The autonomous/semi-autonomous vehicles need to collect and process large amount of data at real time and these data are dynamic in nature.

## 5.3 Heterogeneous Design

Traditional autonomous/semi-autonomous vehicles system approves a united architecture, that is to allocate each function to one ECU and attach numerous ECUs through buses like CAN and FlexRay. This strategy style leads to 30–80 ECUs controlling dozens of complex physical processes. In our proposed approaches we are trying to reducing the number of ECUs due to the increasing complexity of autonomous/semiautonomous vehicles driving applications. This pointers to a replacement of united architecture with integrated design, where software tasks are assigned to a heterogeneous platform with single core or multi-core processors and possibly accelerators such as GPUs and FPGAs for computationally-intensive applications. The embedded hybrid architecture design for such platforms will become meaningfully more difficult and challenging.

# 6 Proposed Framework

## 6.1 Modelling of Software

The propose software model can be captured by a synchronous reactive task graph shown in Fig. 1. Synchronous software models are prevalent practice for modelling control centric cyber-physical systems in fully automotive or semi automotive and avionics domain, and used in popular tools such as Simulink. Synchronous software system contains a fixed set of synchronized communicating processes, as shown in the software model in Fig. 2. For timing analysis, many timing-related parameters need to be abstracted from the synchronous reactive model. For tasks, the most important parameters are the execution time in worst-case is $ET_{Ti}$ for task $Ti$ on certain ECU, and the period activation is $T_{Ti}$. For messages, the most import parameters are total length message $L_{Mi}$ for message $Mi$, the message period $T_{mi}$, and the source and destination tasks of the message $mi$.

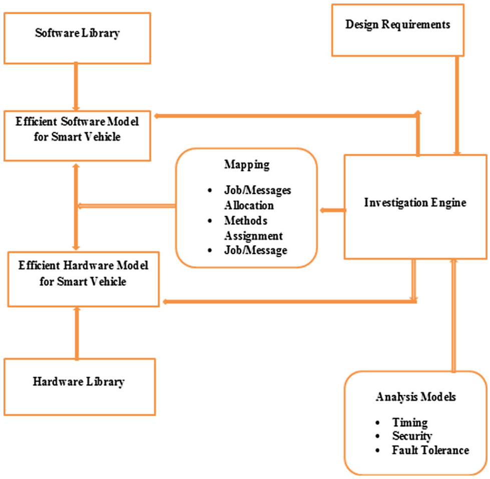


**Fig. 1.** Framework for proposed design architecture

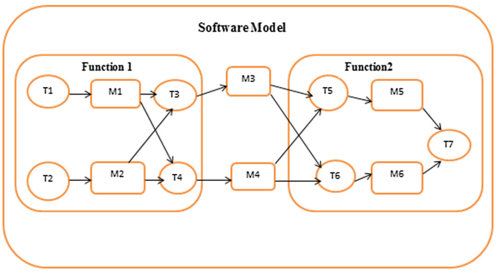


**Fig. 2.** Example of proposed software model

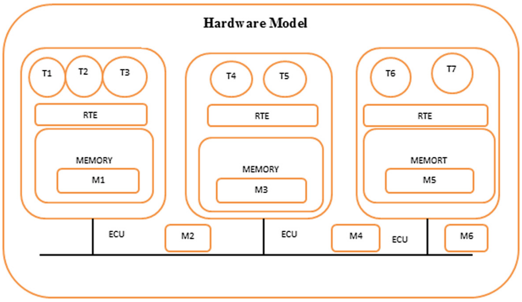


**Fig. 3.** Example of proposed hardware model

### 6.2 Modelling of Hardware

The propose hardware model can be taken through hybrid architecture explanation languages, i.e., architecture modeling and description language (AADL). AADL language captures the system through components, and each component is characterized by its identity, large number of interfaces, some properties and subcomponents. The proposed hardware architecture for autonomous/semi-autonomous vehicle is shown in Fig. 3 where different type of buses such as Ethernet, CAN and FlexRay are connected through the gateway, and high speed computation units which include the ECU, FPGA and GPU are connected to the bus system.

### 6.3 Traffic and Environmental Data Analysis Modelling

The Traffic and Environmental Data analysis models refer to the advanced mathematical models used to quantitatively study various new metrics of automotive/semi automotive system. The various new metrics are timing, reliability, security and fault tolerance.

**Task Model.** In our propose model, every task is required to finish its execution before a specific deadline (typically set as its activation time slots). The task response time $R_{Ti}$ in worst case is represents the large time it may take to finish task $Ti$. If we consider static priority preemptive scheduling (where maximum priority tasks can pre-empt minimum priority tasks), the task response time in worst-case for tasks on the same computation vehicle (i.e. node) can be presented in Eq. (1). The task response time in worst-case includes the worst-case execution time $ET_{Ti}$. $MaxP(Ti)$ denotes the set of maximum priority tasks on the same core.

$$R_{Ti} = ET_{Ti} + \sum_{T_k \epsilon p_T i} (\lceil \frac{R_{Ti}}{T_{Tk}} \rceil) ET_{Ti} \tag{1}$$

**Message Model.** As a distributed system, different type of buses such as Ethernet, CAN and FlexRay are connected through the gateway, and high speed computation units which includes the ECU, FPGA and GPU are connected to the bus system. The messages can be transmitted on CAN bus or through memory. The message access latency for the messages in memory is assumed to be a small constant in our propose model. However, the latency for messages transmitted on CAN bus should be carefully studied in the proposed model. For instance, for the prevalent CAN bus protocol that uses non-preemptive scheduling algorithm, the message response time in worst-case $R_{Mi}$ for message $Mi$ can be represent as Eq. (2). $T_{Mi}$ represents the transmission time in worst-case for transmuted and generated message $Mi$, and $BT_{max}$ represent the maximum blocking time (approximated as the highest transmission time of any generated and transmitted message in the system). Similarly, $MaxP(Mi)$ represents the set of highest priority messages on the same bus in the buses.

$$R_{mi} = ET_{mi} + BT_{max} + \sum_{m_j \epsilon p_m i} (\lceil \frac{R_{Mi}}{T_{Mk}} \rceil) ET_{Mj} \quad (2)$$

**End to End Delay Model.** In automotive/semi-automotive system, the deadlines can also be set on functional paths from source to destination. The path delay or end to end delay from the action of pressing brake to the action of the corresponding actuator should be bounded within a present value to ensure safety. The worst end-to-end delay for path $p$ can be calculated based on the Eq. (3). Because of the asynchronous nature of the communication, task and message periods may need to be added. The details of calculating path latency using a formula (3).

$$L_p = \sum_{T_i \epsilon p} (R_{Ti} + T_{Ti}) + \sum_{M_i \epsilon p} (R_{Mi} + T_{Mi}) \quad (3)$$

**Proposed Optimization Model.** A new quantitative mathematical for fully autonomous or semi-autonomous vehicle for optimization consists of a new objective function and a set of limitations in the form of a system of equations or inequalities. Propose optimization prototypes are used comprehensively in almost all areas of decision-making, such as vehicular architecture design, verification, safety, validation, fault tolerance and security. This paper presents a motivated and organized process for new optimization problem formulation, design of optimal strategy, and quality-control tools that include safety, validation, verification, security, and post-solution activities. By applying the quantitative or mathematical models, the investigation can be done by solving the optimization problem or simply finding a feasible solution to the problem. Besides the timing properties, we can set constraints such as response time in worst case $R_{Ti}$ must be lower than a execution time, $ET_{Ti}$ in worst case and worst case response time for message $R_{Mi}$ must be lower than message period, $T_{Mi}$. We can also set the time constraints such as path delay, $L_p$ must be lower than $D_p$ and security level $Sec$ must be higher than a value $S_0$. We can also set constraints such as reliability level $Rel$ must be higher than a preset value REL0 and throughput and fault tolerance level must be higher than $TPT_0$ and $FLT_0$.

Optimize Objective Function for Design

$$s.t.R_{Ti} \leq ET_{Ti}(Timing) \tag{4}$$

$$R_{Mi} \leq ET_{Mi}(Timing) \tag{5}$$

$$L_p \leq D_p(Timing) \tag{6}$$

$$Rel \geq REL_0(Reliability) \tag{7}$$

$$Sec \geq S_0(Security) \tag{8}$$

$$Tpt \geq TPT_0(Throughput) \tag{9}$$

$$Fault \leq FLT_0(FaultTolerance) \tag{10}$$

# 7 Limitations and Possible Solutions

Given below are a few of the known limitations and possible solutions:

## 7.1 Limitations

- For Authentication and Confidentiality, it isn't mentioned which cryptographic technique should be used.
- If the common bus is failed, either LIN, MOST or CAN then whole system fails or partially affects the system performance.
- If any one of the ECU failed, it should not affect the overall braking system.
- If number of ECU increased, then framework will be more difficult.
- It is mentioned that CACC, Cooperative Adaptive Cruise Control directly make use of the leading vehicles velocity and acceleration, through the information from DSRC. If the obtained information is false, then there is a chance for collision between two vehicles.
- Once the attacker gained access to in-vehicle, they directly access all devices.

## 7.2 Possible Solutions

1. For ensuring Authentication and Confidentiality these mechanisms can be used.
   - User Ownership: A driver owns some unique identity (e.g.: identity card, driving licence etc.).
   - Human Knowledge: A user knows some unique things (e.g.: passwords, human responses through secret questions etc).
   - Biometric Clarifications: These include the signature, thump expression, face and voice.

2. A thumb expression and password mechanism can be added to increase the security of the car, whenever an attacker gain access (in this case only the car owner can drive).
3. In CACC, an additional mechanism can be added that is whenever the values of acceleration and velocity comes from the leading vehicle, instead of using directly, if it is authenticated by the actual forwarder, then a higher level of security can be achieved.

## 8 Conclusion

The design of new hybrid architecture for autonomous or semi- autonomous or human driving vehicles is great challenges, from the increasing the generation and transmission of data volume from the environment, the usage of real life heterogeneous architecture, and the necessity to address multiple aspect and sometimes contradictory, the new design metrics for smart city communication such as consistency, safety and performance. We propose a novel hybrid model-based architecture for automotive/semi-automotive/human driven vehicle modelling and exploration for smart cities for handling these problems. By formally modelling software and hardware architecture with crucial abstracted some new properties; design space investigation is conducted through quantitative analysis. By resolving numerous optimization problems in case of smart city communications, we can achieve decisions such as task to electronic control unit (ECU) allocation, task scheduling, message allocation, message scheduling, security methods assignment and fault tolerance procedures assignment for smart communication.

**Acknowledgement.** The author gratefully acknowledge the support from the SERB-DST Early Research Award $ECR \setminus 2015 \setminus 0256$ and the BITS RIG award 2016.

## References

1. Zheng, B., Liang, H., Zhu, Q., Yu, H., Lin, C.W.: Next generation automotive architecture modeling and exploration for autonomous driving. In: IEEE Computer Society Annual Symposium on VLSI, pp. 53–58 (2016)
2. Pedroza, G., Apvrille, L., Pacalet, R.: A formal security model for verification of automotive embedded applications. In: SAFA, pp. 1–4 (2010). https://doi.org/10.13140/RG.2.1.4890.1609
3. Zheng, B., Li, W., Deng, P., Gérard, L., Zhu, Q., Shankar, N.: Design and verification for transportation system security. In: Proceedings of the 52nd Annual Design Automation Conference, pp. 1–6 (2015). Article No. 96
4. Lin, C. W., Yu, H.: Invited - cooperation or competition?: coexistence of safety and security in next-generation ethernet-based automotive networks. In: 53rd Annual Design Automation Conference, pp. 1–6 (2016). Article No. 52
5. Schatz, B., Voss, S., Zverlov, S.: Automating design-space exploration: optimal deployment of automotive SW-components in an ISO26262 context. In: Proceedings of the 52nd Annual Design Automation Conference (DAC), pp. 1–6 (2015)

6. Oetjens, J.H., Bannow, N., Becker, M., Bringmann, O., Burger, A., Chaari, M., Chakraborty, S., Drechsler, R., Ecker, W., Gruttner, K.: Safety evaluation of automotive electronics using virtual prototypes: state of the art and research challenges. In: Proceedings of the 51th Annual Design Automation Conference (DAC), pp. 1–6 (2014)
7. Eberl, M., Gla, M., Teich, J., Abelein, U.: Considering diagnosis functionality during automatic system-level design of automotive networks. In: Proceedings of the 49th Annual Design Automation Conference, pp. 205–213. ACM (2012)
8. Yu, H., Joshi, P., Talpin, J.P., Shukla, S., Shiraishi, S.: The challenge of interoperability: model-based integration for automotive control software. In: Proceedings of the 52nd Annual Design Automation Conference, pp. 51–58 (2015)
9. Shahbakhti, M., Amini, M.R., Li, J., Asami, S., Hedrick, J.K.: Early model-based design and verification of automotive control system software implementations. J. Dyn. Syst. Meas. Control **137**(2), 021006 (2015)
10. Zhu, Q., Zeng, H., Zheng, W., Natale, M.D., Sangiovanni-Vincentelli, A.: Optimization of task allocation and priority assignment in hard real-time distributed systems. ACM Trans. Embed. Comput. Syst. (TECS) **11**(4), 1–30 (2012)
11. Zheng, B., Deng, P., Anguluri, R., Zhu, Q., Pasqualetti, F.: Crosslayer codesign for secure cyber-physical systems. IEEE Trans. Comput.-Aided Des. Integr. Circuits Syst. **35**(5), 699–711 (2016)
12. Jo, K., Kim, J., Kim, D., Jang, C., Sunwoo, M.: Development of autonomous car part I: distributed system architecture and development process. IEEE Trans. Ind. Electron. **61**(12), 7131–7140 (2014)
13. Kordes, A., Vermeulen, B., Deb, A., Wahl, M.G.: Startup error detection and containment to improve the robustness of hybrid FlexRay networks. In: IEEE Design, Automation and Test in Europe Conference and Exhibition (DATE), pp. 1–6 (2014)
14. Zhu, Q., Zeng, H., Zheng, W., Natale, M.D., Sangiovanni-Vincentelli, A.: Optimization of task allocation and priority assignment in hard real-time distributed systems. ACM Trans. Embed. Comput. Syst. (TECS) **11**(4), 85–95 (2012)
15. Zheng, B., Deng, P., Anguluri, R., Zhu, Q., Pasqualetti, F.: Crosslayer codesign for secure cyber-physical systems. IEEE Trans. Comput.-Aided Des. Integr. Circuits Syst. **35**(5), 699–711 (2015)
16. Davare, A., Zhu, Q., Di Natale, M., Pinello, C., Kanajan, S., Sangiovanni-Vincentelli, A.: Period optimization for hard real-time distributed automotive systems. In: ACM Proceedings of the 44th Annual Design Automation Conference, DAC, pp. 278–283 (2007)
17. Zheng, B., Lin, C.W., Yu, H., Liang, H., Zhu, Q.: CONVINCE: a cross-layer modeling, exploration and validation framework for next-generation connected vehicles. In: ICCAD, pp. 1–8 (2016)
18. Das, D., Misra, R.: Parallel processing concept based vehicular bridge traffic problem. In: Kumar Kundu, M., Mohapatra, D.P., Konar, A., Chakraborty, A. (eds.) Advanced Computing, Networking and Informatics- Volume 2. SIST, vol. 28, pp. 1–9. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-07350-7_1
19. Das, D., Misra, R., Raj, A.: Approximating geographic routing using coverage tree heuristics for wireless network. Wirel. Netw. (WINE) **21**(4), 1109–1118 (2015). Springer US
20. Das, D., Misra, R.: Improvised k-hop neighborhood knowledge based routing in wireless sensor networks. In: IEEE International Conference on Advanced Computing, Networking and Security (ADCONS), pp. 128–134 (2013)

21. Petrenko, A., Timo, O.N., Ramesh, S.: Model-based testing of automotive software: some challenges and solutions. In: 52nd ACM/EDAC/IEEE Design Automation Conference (DAC), pp. 1–6 (2015)
22. Krishna, S.N., Narwane, G., Ramesh, S., Trivedi, S.: Compositional modeling and analysis of automotive feature product lines. In: Proceedings of the 52nd Annual Design Automation Conference, pp. 1–6 (2015). Article no. 57