

## Research Article

# Formal Verification on the Safety of Internet of Vehicles Based on TPN and Z

Yang Liu<sup>1</sup>, Liyuan Huang<sup>1</sup> and Jingwei Chen<sup>2</sup>

<sup>1</sup>Information Science and Engineering, Chongqing Jiaotong University, Chongqing 400074, China

<sup>2</sup>Chongqing Key Laboratory of Automated Reasoning and Cognition, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714, China

Correspondence should be addressed to Jingwei Chen; chenjingwei@cigit.ac.cn

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Nowadays, the Internet of Vehicles has become the focus of global technological innovation and transformation in the automotive industry. Its flow modelling appears to play a very important role for designing and controlling the transportation systems, since it is not only necessary for improving safety and transportation efficiency but also can yield a series of society, economy, and ecosystem environment problems. Considering the characteristics of the frame structure includes states and actions and discrete and continuous aspects of traffic flow dynamics, both petri net and Z have proved to be useful tools for modelling the Internet of Vehicles. It can formally describe the vehicle behavior accurately with petri net and more details with Z frame structure. A new integration formal method of time petri net and Z is presented in this paper for modelling the vehicle behaviors and traffic rules through taking into account state dependencies on external rules. Moreover, a case study in the Internet of Vehicles is proposed to deal with the accurate localization of events. It shows that this formal verification methods significantly improves the safety and intelligence of the Internet of Vehicles.

## 1. Introduction

With the development of communication technology, wireless sensing technology, automatics, artificial intelligence, and so on, the Internet of Vehicles techniques come out. It is the achievements combined with the latest technological of computers and the modern automobile industry. Because of the complex and dynamic environment when it is working, the control system becomes more and more complex. Since it is about life, the key safety factor, such as automotive engine, air bag control, brake system, sensor monitoring system, and traffic regulations, have very strict reliability requirements. Internet of Vehicles has made our life convenient; nevertheless, at the same time, accidents still happen often. Many researchers ensure the safety from different aspects [1–3] by different methods, such as control strategy, security factor, and intelligent platform. More and more experiences show that the formal method is very effective to ensure the safety of the Internet of Vehicles [4–7] systems.

In fact, the formal method is a good way to inspect the problems in system design or requirement design [8, 9]. The running environment of the Internet of Vehicles is very complex and changes dynamically. It is hard to describe the Internet of Vehicle using only one single formal language.

The traditional process analysis methods, such as Petri nets [10], CCS (Calculus of Communicating Systems) [11, 12], and CSP (Communication Sequential Processes) [13, 14], can model different aspects of the system from different angles and abstractions, but the powers of description for functional and nonfunctional attribute and constraint condition are deficient. The traditional model languages such as V [15, 16], B [17], and Z [18, 20] are good at modelling description, but poor at describing system concurrency. At present, the integrated specification languages are a hot topic, which produced CSPZ [21], TCOZ [22], PZN [23, 24], and so on. However, it seems that these languages do not aim at the Internet of Vehicles. PZN has a good advantage in describing traditional systems, since specification Z has a good frame structure both in state description





















