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Modelling and Analysis of Microchipped Equipped Number Plate for Car Tracking System Using 'UPPAAL'

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Abstract

This paper presents the design and analysis of microchip equipped car number plate integrated with GPS car tracking system. A Microchipped car number plate is a technology where chips are embedded on number plates. The microchip can store data of the car owner, including registration details, chassis number and other necessary road traffic details and the car can be scanned from distance using chip-readers. The information on the plates can be used to quickly pick up vehicles which are on the road illegally. It can also help to eliminate vehicle theft, detect unlicensed and uninsured vehicles, and allow road traffic officer or law enforcement agent to trace and follow any vehicle without the need for this officer's car to be within miles. UPPAAL is used for the design and analysis of microchip equipped car number plate integrated. The model-checker UPPAAL based on the theory of timed automata and its modelling language offers additional features such as bounded integer variables and urgency. Results of our model show quick synchronisation of data captured from GPS tracking device and chip-readers. We note, however, that many numbers of states are covered in the modelling which caused delays in early termination and reachability analysis of the model as potential limitation of our proposed system.

Keywords: Microchips; number plate; tracking system; chip-readers; model-checker UPPAAL.

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1 Introduction

Microchipped car number plates is a technology where chips are embedded on number plates. The microchip can store data of the car owner, including registration details, chassis number and other necessary road traffic details. It can be scanned using chip-readers from a distance of up to 100 metres. Further to its renewed determination to harmonize and unify all existing modes of licensing of vehicles nationwide, the Federal Road Safety Corps (FRSC) in Nigeria has concluded plans and started rolling out the proposed new vehicle number plates. According FRSC Corps Marshal, the new vehicle number plates form part of corps' strategies towards restoring order and sanity in the nation's motor vehicle administration scheme adding that under the new arrangement, number plates will be attached to vehicle owners with an identification tag bearing the number plates, affixed to the windscreen for ease of security checks [1]. The implementation of this scheme according to FRSC will bring about quality management system and total overhaul of the national vehicle identification scheme which will require vehicle owners to exchange their present number plates for the new ones. On the features of the number plates, the Corps Marshal disclosed that aside from improved security features, the number plates would come with bolder embossed character and the 50th Nigerian anniversary commemorative logo [1].

FRSC plan was highly criticised, a lawyer filed an action challenging the constitutionality and the legality of the plan of the Federal Road Safety Commission to embark on the issuance of new vehicle number plates and drivers' license exercise all over the country. Some people even complained that the cost of the new number plates is on the higher side [1].

The major difference between the existing and the new number plates by FRSC is that the new number plates would come with 50^{th} Nigerian anniversary commemorative logo and bolder embossed character than the existing one. This will not take much time before men of the underworld would outsmart FRSC new number plates system because the new one is not coming with any new high tech.

In view of these, we proposed microchipped car number plate, in our model, the registration number plates will have RFID (Radio Frequency Identification) technology, which will make it easier for the FRSC and police to get details about driver and vehicle. The proposed system will enable FRSC to use the information on the plates to quickly pick up vehicles which are on the road illegally. It will also help in getting details of cars which are over speeding or breaking traffic rules. In the nearest future, these high-tech number plates can be used for automatic toll collections; a system wherein, the toll amount can be debited from the vehicle owners' account the moment the vehicle passes a predetermined check post.

Modelling and simulation for performance analysis of system play an important role in the design process of complex embedded systems. It allows analyzing essential performance characteristics of a system design at an early phase and consequently supports the choice of important design decisions before much time and resources are invested in detailed implementation.

Embedded system design consists of both hardware and software with complexity varies from low, with a single microcontroller chip, to very high with multiple units of interconnection of individual microcontroller chips to form distributed embedded systems integrated with software. The design of embedded system is quiet demanding and the designer finds it difficult to embark on its actual realisation without pre-design modelling, simulation and verification.

In this paper, we used 'UPPAAL', a tool for performance analysis of real-time embedded systems for modelling and simulation of our proposed microchipped vehicle number plate with the following contributions:

- Introduction of intelligent car number plates embedded with microchips instead of bolder embossed character number plates proposed by FRSC
- Integration of microchipped car number plate with GPS car tracking system to eliminate vehicle theft, detect unlicensed and uninsured vehicles, and to allow FRSC and police to trace and follow any vehicle without the need for a police/FRSC car to be within miles.

The rest of the paper is organised as follows: Section 2 focuses on overview of UPPAAL, sections 2.1 and 2.2 are on system requirement and formal system functionality respectively. Section 3 is on formal modelling of proposed microchipped integrated tracking system while section 4 is on validation and verification of results. Future work and related work are discussed in sections 5 and 6 respectively. Section 7 concludes the work.

2 Overview of UPPAAL

In this section, we briefly give an overview of UPPAAL, outline its uses and some applications. UPPAAL is used for modelling and verification of timed automata networks to alleviate the challenges of the designer. Timed automata is a popular formalism for the specification of real- time embedded systems. It can be used in combination with a logic language to verify system properties by model checking [2]. The UPPAAL tool environment allows users to validate and verify real-time systems modelled as networks of timed automata [3]. UPPAAL is a tool suite for symbolic model checking of real-time [4], jointly developed at the University of Uppsala (Sweden) and Aal-borg (Denmark). Besides model checking, it also supports simulation of timed automata and has some facilities to detect deadlocks. UPPAAL has been applied to several industrial case studies such as real-time protocols, multi-media synchronization protocols and also to communication protocols [5]. The first version of UPPAAL was released in 1995. Since then it has been in constant development [6]. Experiments and improvements include data structures, partial order reduction, symmetry reduction, a distributed version of UPPAAL, guided and minimal cost reachability, work on UML statecharts, acceleration techniques, new data structures and memory reductions [7].

The current version of the tool is 4.0.11. It features a Java user interface and a verification engine written in C++. The academic version of UPPAAL can be downloaded freely from UPPAAL website. An overview of the model checker UPPAAL is given in Fig. 1. For reasons of efficiency, the model checking algorithms that are implemented in UPPAAL are based on (sets of) clock constraints rather than on explicit (sets of) regions.

The property that each region can be expressed by a clock constraint over the clocks involved is exploited. By dealing with (disjoint) sets of clock constraints, a coarser partitioning of the (infinite) state space is obtained [8]. UPPAAL facilitates the graphical description of timed automata by using the tool AUTOGRAPH. The output of AUTOGRAPH is compiled into textual format using component atg2ta, which is checked by checkta for syntactical correctness. This textual representation is one of the inputs to UPPAAL'S verifyta. The verifier can be used to determine the satisfaction of a given real time property with respect to a timed automaton.

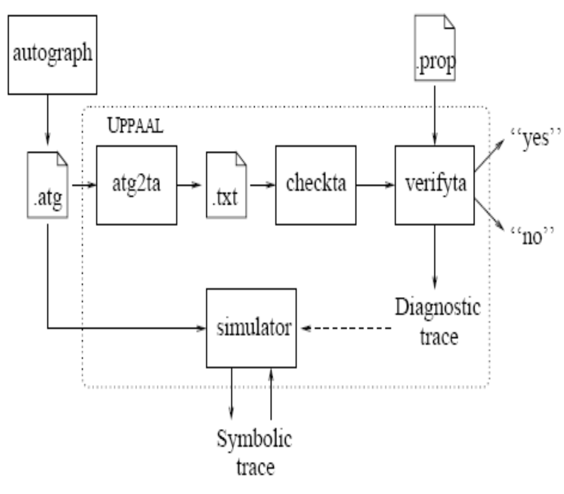

Fig. 1. An overview of the model checker UPPAAL

If a property is not satisfied, a diagnostic trace can be generated that indicates how the property may be violated. UPPAAL also provides a simulator that allows a graphical visualization of possible dynamic behaviours of a system description (that is, a symbolic trace). The diagnostic trace, generated in case a property is violated, can be fed back to the simulator so that it can be analyzed with the help of the graphical presentation. To improve the efficiency of the model checking algorithms, UPPAAL does not support the full expressivity of TCTL (Timed computation tree logic), but concentrates on a subset of it that is suitable for specifying safety properties.

2.1 System Requirements

Vehicle tracking system is a combination of an electronic device installed in a vehicle with special purpose computer software in one or more operational base. This makes tracking of vehicle either by the owner or third party seamless because data can be collected and delivered to the base of operation. GPS (Global Positioning System) or GLONASS (Global Orbiting Navigation Satellite System) technology are used nowadays for tracking vehicle. Presently automatic vehicle location technology is being used to view vehicle information on electronic maps via the internet or specialized software [9].

GPS captures and transmits the vehicle location information at regular intervals to a central server.

With proper synchronisation, GPS can capture other vehicle information such as fuel amount, engine temperature, altitude, reverse geocoding, door open/close, tyre pressure, cut off fuel, turn off ignition, turn on headlight, turn on taillight, battery status, GSM area code/cell code decoded, constellation GPS satellites in view, glass open/close, fuel amount, emergency button status, cumulative idling, computed odometer, engine RPM, throttle position and a lot more. Capability of these devices actually plays a major role in the accuracy of the whole tracking system. The information captured are received and securely stored by GPS tracking server. The information is released to the user on demand. User interface accesses the information, views vehicle data, and elicits important details from it. GPS vehicle tracking devices are classified as passive and active. Passive devices store GPS location, speed, heading and sometimes a trigger event such as key on/off, door open/closed. Once the vehicle returns to a predetermined point, the device is removed and the data downloaded to a computer for evaluation. Passive systems include auto download type that transfer data via wireless download. Whereas active devices also collect the same information but usually transmit the data in real-time via cellular or satellite networks to a computer or data centre for evaluation.

In our proposed system, both active and passive tracking abilities are combined. When a cellular network is available and a tracking device is connected it transmits data to a server but the device stores data in internal memory when network is not available and will later transmit stored data to the server when the network becomes available again. Our proposed system is made up of new number plates that contain electronics (microcontroller) secreted within the plastic and programmed with details of the vehicle including its unique identification number which is related to the owner, type and colour. These will be readable by roadside detectors (chip-readers) mounted on poles and lighting gantries and picked by surveillance cameras installed on tall poles alongside many major roads. Unlike speed cameras they would be disguised to help prevent vandalism. The vehicle picked by surveillance cameras will constantly be tracked by GPS tracking system.

2.2 Formal System Functionality

In this section, we formally describe the functionality of our proposed system, abstract behaviour of the system in the environment based on the desired informal specification requirements identified above and finally model the system.

2.2.1 Performance specifications

The performance specifications of our model are as follow:

a) The vehicle should be detected within the range of 200 meters
b) The vehicle identity should be acquired within 100 meters

c) Vehicle details should be confirmed within 45 seconds
d) Police should be alerted within 10 seconds if vehicle details is suspicious
e) Vehicle should be declared as unregistered within 10 seconds if vehicle details could not be confirmed
f) System should alert FRSC within 5 seconds for possible arrest if the vehicle is on the road illegally.
g) FRSC should be alerted within 10 seconds if vehicle has passed maximum speed limit

2.2.2 Predictability

The essence of predictability requirements are to ensure strict synchronisation and control between vehicles equipped with microchipped number plates and GPS tracking system.

a) GPS tracking system should be installed on the vehicle.
b) Vehicles should be equipped with functional microchipped number plates during tracking

3 Formal Modelling of Proposed Microchipped Integrated Tracking System

Tracking central server correlates data received from chip-readers server and GPS tracking server: The tracking central server perform the following responsibilities: receive data from the GPS tracking unit, securely storing it, and serving this information on demand, that is in response to user query on a particular vehicle.

We modelled the integration of existing GPS tracking device and microchipped car number plates fit into the vehicle (see Fig. 2). GPS captures the specific location information at regular intervals to a central server. Chip-readers (detectors) read the unique identification number of the vehicle number plates to central server. The data are then synchronised to obtain vehicle details. Each component is with corresponding request service(s) as input and get service(s) as output.

These components are modelled using UPPAAL by the automata VEHICLE_SURVEILLANCE and TRACKING_COORDINATION. The environment is modelled by automata VEHICLE_DETECTION and VEHICLE_TRACKING.

Each of the automata is verified separately before being integrated to enable formalisation and verification of these requirements. The integration is achieved by using broadcast synchronisation, where sender **chan**! synchronises with an arbitrary number of receivers **chan**? In our model, the *Ident!* channel of automaton VEHICLE_DETECTION synchronises with *Ident?* of VEHICLE_SURVEILLANCE automaton.

3.1 Simulation of Microchipped Integrated Tracking System Using UPPAAL

3.1.1 Vehicle detection

Vehicles are detected within the range of 200 meters, in automaton VEHICLE_DETECTION (Fig. 3), the transmission occurs periodically at one second intervals and it intends to enable vehicle detection. Microchipped number plates of detected vehicle is scanned and its identification, Ident is acquired within 20 seconds. In the VEHICLE_DETECTION automaton the Detector state starts broadcasting and if vehicle is detected, it is scanned in state *VScan* which transmits its identification to server. *Ident!* channel from *VIdent* location *of* VEHICLE_DETECTION synchronises with *Ident?* of VEHICLE_SURVEILLANCE automaton.

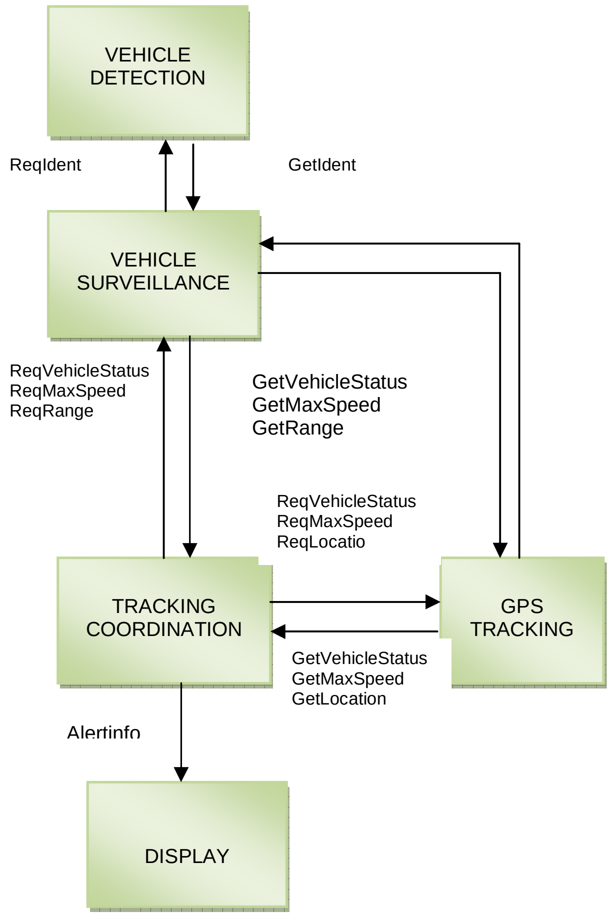

Fig. 2. Integrated Microchipped car number plates with GPS car tracking system

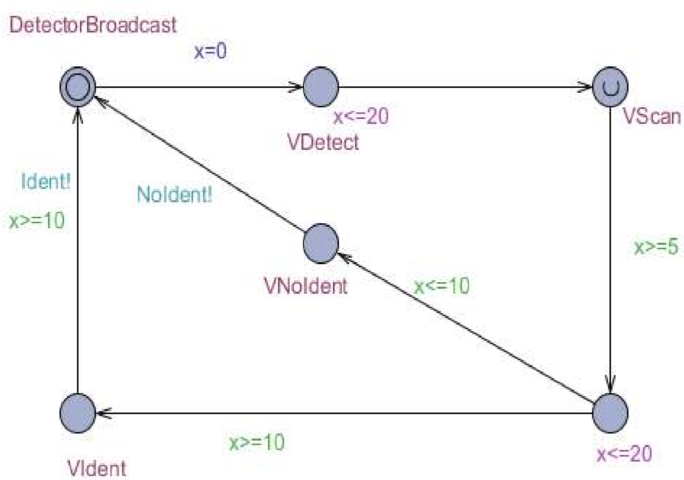

Fig. 3. The VEHICLE_DETECTION automaton

3.1.2 Vehicle surveillance

After vehicle has been identified, the automaton VEHICLE_SURVEILLANCE (Fig. 4) starts within 5 seconds. Transition is from *start* to *initialise* location, *VIdentAcqd* and *status.* It remains in this location for an invariant constraint of 5 seconds to determine whether the vehicle is registered or not.

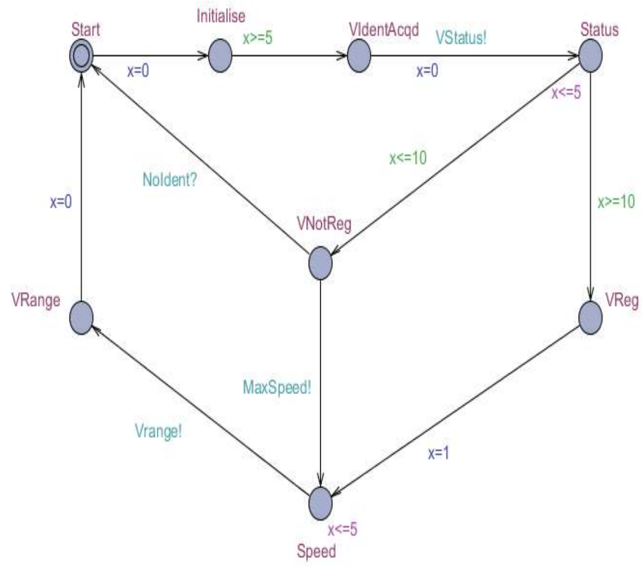

Fig. 4. The VEHICLE_SURVEILLANCE automaton

In the determination of vehicle registration status, the guard constraint x>=10 and x<=10 determines the vehicle status, guard constraint x>=10 from location status enables *VReg* (vehicle is registered) and x<=10 enables *VNotReg,* (vehicle is not registered).

The request channels *VStatus!*, *MaxSpeed!* and *Vrange!* synchronise with corresponding services output channel *VStatus? MaxSpeed?* and *Vrange?* of VEHICLE_TRACKING automaton of Fig. 5.

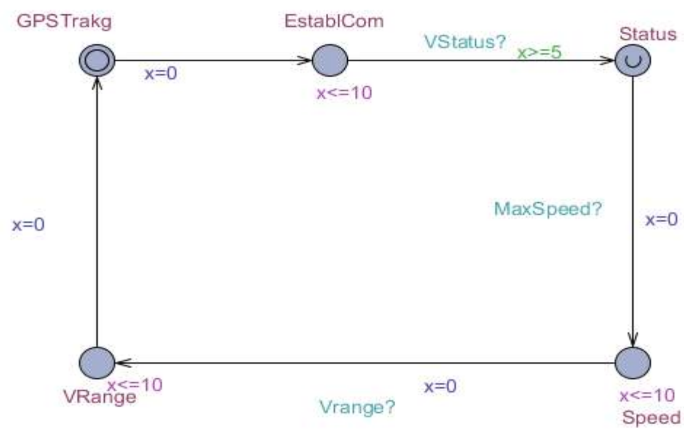

Fig. 5. The VEHICLE_TRACKING automaton

3.1.3 Vehicle tracking

GPS tracking is performed continuously. The nominal time interval between the interrogations is one second. Transition is delayed for a maximum of 10 seconds in location *EstablCom* to enable synchronisation with data captured by surveillance camera in VEHICLE_SURVEILLANCE automaton. The vehicle is tracked within 5 seconds and the vehicle *Status, Speed* and *Range* services output are acquired (See Fig. 5).

3.1.4 Tracking coordination

Data received from VEHICLE_SURVEILLANCE automaton is synchronised with VEHICLE_TRACKING automaton in TRACKING_COORDINATION automaton. The transition is from *VBroadcast to VDetect, VIdent* and *ServerSyn* location. Then from *VOffencedetecd* where it has been resolved that the vehicle has violated a particular offence to location *VOffencetag* where the actual offence is tagged to the vehicle and FRSC/police is alerted at *DispAlertinfo* location.

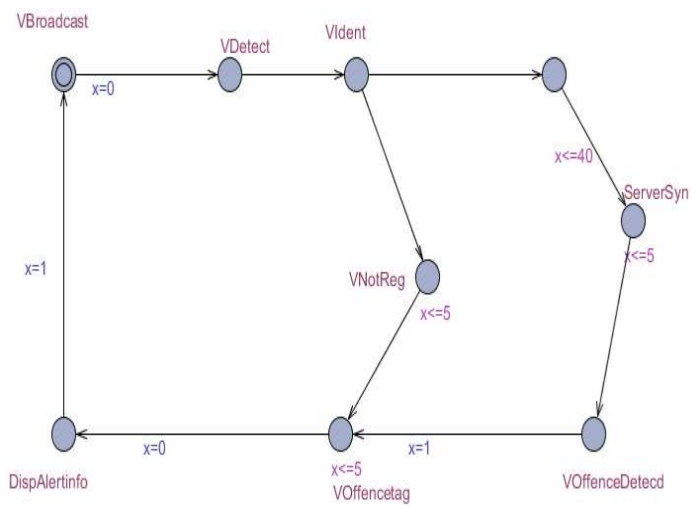

Fig. 6. TRACKING_COORDINATION Automaton

4 Validations and Verification of Results

In this section, we show the formal requirements given in section 2.2 and ascertain their correctness using the symbolic model-checker of UPPAAL to check the state and path formulae for their *rechability*, safety and *liveness.*

We check whether the properties ϕ can be satisfied by any reachable state, that is, given a path starting at the initial state or location, we found out whether such ϕ is eventually satisfied along that path and safely within a given time bound. For example, in the first performance requirement we showed that vehicle equipped microchipped number plates can be detected within 45 seconds. In properties 5, 6, and 7, we showed that if VEHICLE_SURVEILLANCE *Status, Speed* and *Range* captured by surveillance camera and scanned by chip reader is reached then the *Status, Speed* and *Range* in GPS VEHICLE_TRACKING will be reached. This ensures successful integration of microchipped car number plates with GPS car tracking system. If vehicle is confirmed to have committed any offence in *VOffenceDetecd* location, automatically it will be tagged in location *VOffencetag.*

We have been able to use UPPAAL installed on a 1.795 GHz Pentium IV PC equipped with 1GB of RAM to verify various properties of the system (see appendix A). The verification of all the properties consumed 22.6 seconds.

5 Future Work

One of the possible future works is to identify a minimal set of covering states that will ensure early termination and reachability analysis of the system. Also this work can be extended to allow possible integration of our proposed tracking system with Engine Control System of vehicle.

6 Related Work

Vehicle tracking system is in existence nowadays, several techniques have been developed, one is Blob Tracking [10] where moving objects is generated and each frame is compared with the background model to obtain a foreground blob representing the vehicle. Another method is the Active Contour Tracking [10], this method tracks the contour of the foreground blob. We have Feature-Tracking method that uses feature points to track objects [11]. Another method uses GPS technology with cell phone for tracking vehicle [12]. GPS tracking device fits into the vehicle captures GPS location information at regular intervals to a central server and possibly other vehicle information such as fuel amount, engine temperature, altitude and many more. In our proposed tracking system, the existing GPS tracking system technology is integrated with microchipped number plates programmed with unique identification number which is related to the vehicle owner.

7 Conclusion

We modelled the integration of microchipped car number plates with GPS car tracking system to eliminate vehicle theft, detect unlicensed and uninsured vehicles, and to allow FRSC or police to trace and follow any vehicle without the need for a police/FRSC car to be within miles. We verified various performance properties of the system using UPPAAL installed on a 1.795 GHz Pentium IV PC equipped with 1GB of RAM. Instead of paying higher for number plates that will come only with bolder embossed character, implementation of integrated microchipped car number plates with GPS tracking system will go in a long way to improve security and enable car owners to enjoy value for their money.

We note, however, that many numbers of states are covered in the modelling which caused delays in early termination and reachability analysis of the model as potential limitation of our model.

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Competing Interests

Authors have declared that no competing interests exist.

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Appendix- A

E<>VEHICLE_DETECTION.VDetect
E<>(VEHICLE_DETECTION.VIdent imply x<=45)
E<>(VEHICLE_DETECTION.VIdent imply VEHICLE_SURVEILLANCE.VIdentAcqd)
E<>(VEHICLE_SURVEILLANCE.Status imply VEHICLE_TRACKING.Status)
E<>(VEHICLE_SURVEILLANCE.Speed imply VEHICLE_TRACKING.Speed)
E<>(VEHICLE_SURVEILLANCE.VRange imply VEHICLE_TRACKING.VRange)
E<>VEHICLE_SURVEILLANCE.Speed imply (x<=5)
E<>TRACKING_COORDINATION.VOffenceDetecd imply TRACKING_COORDINATION.VOffencetag
E E<>TRACKING_COORDINATION.VOffencetag imply TRACKING_COORDINATION.DispAlertinfo
E<>TRACKING_COORDINATION.VNotReg imply TRACKING_COORDINATION.VOffencetag

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