Application Of Internet Of Things For Cyber-Resilient Automotive Industry: A Systematic Review

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Abstract- The automotive industry is one of the fastest-growing industries has conceivably transformed the world with innovations ranging from the electric, hybrid, and self-driving, smart cars to the progression of the Internet of Things (IoT)-connected cars. Due to its complexity, it necessitates the involvement of some technology industries like the cyber-physical systems and robotics. One of the modern technologies that uphold the industry is the Internet of Things (IoT). The application of IoT enhances its traceability, data security, power, validation, confidentiality as well as durable sustainability and higher operational efficiency to the automotive industry. This systematic review explores the potential of applying IoT to the automotive industry with a focus on cybersecurity features. Consequently, the applicability of IoT to the industry is reviewed following the state-of-the-art and emergent challenges. Based on the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, some recommendations are highlighted to guide industries and academic institutions in the prospects of the cyber-resilient automotive industry.

Keywords: Automotive Industry, Cyber-resilient and Internet of Things

Introduction

The automobile industry is a service industry that sustains the transport sector of a nation's overall economy with a wide range of prime wares namely Sports Utility Vehicles (SUV), trucks, vans and traveller's vehicles. The industry thrives as it deeply focuses on developing, revamping and maintaining nearly all vehicle components and systems such as the engine and related computerized control units and modules, the chassis, suspension and power transmission system (Mustapha, *et.al.,*2019). Additionally, the industry is one of the fast-growing with highly sophisticated innovations such as the electric, hybrid, autonomous and the connected vehicles; which depends on a safe interruptible wireless communication network systems (Abdulkadir *et.al.,* 2019).

Despite the huge benefits of autonomous and connected vehicles; ranging from safer driving to more efficient fuel economy, the risk of malicious attacks cannot be thrown overboard (Morando *et.al.,* 2018). More so, automobile industries face levels of security challenges and operational inefficiencies arising from cyber-attacks; hiked prices of spare parts and services possess levels of challenges as well (Mustapha *et.al.,* 2019). These challenges are not peculiar to automobile industries alone as corporate and private vehicle owners experience them as well. From a holistic view, even the general public safety is at stake when the security and operational efficiencies of mentioned vehicles are compromised (Abubakar, Mustapha & Raji, 2019). For these reasons, it behoves automobile industries to ensure that well-built Internet of Things (IoT) for cybersecurity is an indispensable requisite for resilient vehicles to meet today's demands. Therefore, this paper is a systematic review on the application of Internet of things for cyber-resilient automotive industry.

Automobile Industry

The automobiles are self-driven vehicles that are used mainly on daily basis to transport goods and services by road, from a place of origin to destination (Idris & Mustapha, 2019). However, the automobiles are becoming complicated due to the variation in intended uses, competition among manufacturers, designs and dimensions. This necessitates proficient care due to the development of innovative technologies that have been taking place in the automobile industry (Mustapha *et.al.,* 2019).

The automobile industry is a conglomerate that engages in the research and design, development, selling of vehicles products, fabrication and revamping of power-driven vehicles in concert with almost all parts in the vehicle, such as the body and engine (Abdulkadir, *et.al.,* 2020). Since the days of horse and cart, people have with satisfaction obsessed and keenly heed for their automobiles (Mustapha *et.al.,* 2019). As one of the fastest-growing industry with major modifications such as the transition from dependent vehicles (driven by humans) to independent vehicles (driven by themselves) that is on currently taken place, technology is now evident in the automotive industry through IoT (Mustapha *et.al.,* 2019).

Internet of Things (IoT) in the Automotive Industry

A member of the Radio Frequency Identification (RFID) development community coined the concept of IoT in 1999. It has recently become more relevant to the practical world largely because of the growth of mobile devices, embedded and ubiquitous communication, cloud computing and data analytic (Nuno, 2015). According to The International Telecommunications Union (ITU) (2012), the IoT refers to as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable Information and Communication Technologies. This implies that IoT explains the relationship between any physical object (automobile) and its connection (systems) to the internet or where a physical system and an information system collide. Similarly, according to Nick (2017), stated IoT is a turbulent technology where the cyber world run into the physical world. Therefore IoT is an independent communication between non-living objects to profit human beings. As an emerging paradigm, IoT comes together with three principal innovations namely, things (the objects to trace, things-oriented vision), networking (the linking of the objects to the Internet and connection between the objects, Internet-oriented vision) and representation (the portrayal of the objects on the Internet, semantic-oriented vision).

However, according to the Automotive Tech blog (2019), today, vehicles manufactures incorporate enhanced navigation, advanced safety features, streaming infotainment, integration among dashboard, smartphones and TVs wearables. These systems and devices use a variety of wireless signals such as Bluetooth, LTE and Wi-Fi. IoT also links automobile parts and services, machines, people and vehicles to smooth-running the flow of data, permit real-time judgment and ameliorate automotive experiences (Ruhi et al., 2018).

The existence of smart vehicles was made possible with the help of IoT and as such, the potentials of IoT in the automotive industry support cooperative mobility either in an embedded and tethered form (Davika & Kumari, 2018). The former makes use of an incorporated chipset and aerial in automobiles while the latter utilizes hardware to permit drivers to have a frontier with their vehicles via smartphones. More so, the incorporation of this hardware's is relevant in today's automobiles through the Global Position System (GPS) and Google maps (Ruhi et al., 2018). Supplementary itinerary devices such as the GasBuddy are ongoing to append in the hardware frameworks. For occasion, the GasBuddy aid the

driver to locate a fuel station in their neighbourhoods'. For that reason, the automotive industry is on the threshold of swift change and the might behind this is the Internet of Things (IoT).

Application of Internet of Things to the Automotive Industry

The IoT is making its way to becoming a part of our daily lifestyle. It consists of devices connected over a network that is slowly changing the way we live (Alasdair, 2017). Consumers of IoT devices (such as the automotive industry) can control air temperature with just a couple of clicks. In the automotive industry, IoT enables efficiency on a whole new level, as well as capability management. Milakis, Arem & Vanwee, (2017) state that technology brings us one step closer to the future of smart, autonomous vehicles. The introduction of 5G leaves a field for faster data transfers and response times, as well as enhanced vehicular communication. The need for maximizing productivity and saving time in this fast-paced era will increase the usage of IoT devices. As for the automotive industry, IoT applications open up entirely new opportunities (Mustapha, *et.al.,* 2019).

Connected Cars and Cellular Vehicle-to-Everything (V2X)

V2X is a crash avoidance technology that relies on communication of information between nearby vehicles and infrastructure to warn drivers about potentially dangerous situations that could lead to crashes. For example, V2X helps warn drivers that a vehicle ahead is braking and they need to slow down or let a driver know that it is not safe to proceed through an intersection because another car, unseen by the driver, is quickly approaching (Shaoshan, *et.al.,* 2020).

Today connected cars are more than just about location tracking. The Cellular Vehicle-to-Everything (C-V2X) standard, established by the 3rd Generation Partnership Project, supports the future of connected cars and allows backward compatibility (Kamal, *et.al.,* 2015). Bansal and Kockelman (2017) highlighted that C-V2X has two models of operation, namely:

iii. **Device-to-network:** It supports vehicle-to-network communications via cellular networks. This allows cloud services to be also included in these solutions, also real-time traffic responding and routing. This connection allows vehicles to support data streaming capabilities.

iv. **Device-to-device:** This supports communications like vehicle-to-vehicle, vehicle-to-pedestrian, and vehicle-to-infrastructure. They open up more than just connected cars. These communications make connected roadways, through innovations like traffic signal priority or collision avoidance for instance.

V2X includes communication between vehicles and infrastructure (V2I, or “vehicle to infrastructure”) and communication among vehicles (V2V, or “vehicle to vehicle”). Sharing mobility information between vehicles and road infrastructures requires continuous communication for up to date information about vehicle states and their environment. On-board units and roadside units (vehicle and infrastructure) constantly send and receive messages. V2X devices in cars are often referred to as an On-Board Unit (OBU), whereas a V2X device installed on the road infrastructure is called a Road-Side Unit (RSU).

Vehicle-to-vehicle (V2V): The automobile has undergone countless transformations over the years but none may compare to its latest innovation. Vehicle-to-Vehicle (V2V) communication is revolutionizing how cars on the road interacting with one another (Rodriguez, 2017). It supports wireless protocol for ease communication between or among

vehicles. This wireless protocol is similar to Wi-Fi, it is called Dedicated Short Range Communications (DSRC). It uses frequency bands in combines with GPS technology to provide the low-cost V2V communication system between or among similarly equipped vehicles within communication range (Harding, *et.al.,* 2014).

Vehicle-2-vehicle (V2V) communication enables several different safety applications:

1. Intersection Movement Assist (IMA) warns the driver when it is unsafe to enter an intersection because of the high potential for a collision with one or more vehicles.
2. Left Turn Assist (LTA) warns the driver there is a high probability they will collide with an oncoming vehicle when making a left turn. This is critical when the driver's line-of-sight is blocked by a vehicle.
3. Emergency Electronic Brake Light (EEBL) warns the driver to be prepared to take action when a vehicle ahead is braking. V2V allows the driver to see through other vehicles or poor weather conditions to know that traffic ahead is coming to an abrupt stop.
4. Forward Collision Warning (FCW) alerts the driver of the risk of an impending rear-end collision with another vehicle in traffic, in the same lane, and the direction of travel.
5. Blind Spot Warning (BSW) and Lane Change Warning (LCW) notifies the driver when a vehicle in an adjacent lane is positioned in the driver's "blind spot" zone.
6. Do Not Pass Warning (DNPW) tells the driver that it is not safe to pass a slower-moving vehicle because vehicles are approaching from the opposite direction in the passing lane.

Transmitted messages common to all vehicles include current GPS position, vehicle speed, acceleration and heading, vehicle control information, vehicle path history and predication. However, it does not support internet access, assisted services rearview cameras and other advanced technologies. Furthermore, the V2V system provides drivers with crucial information when they need it via several embedded applications such as the intersection movement assist which warns for unsafe intersection, the do not pass which warn when it is unsafe to pass a slower moving vehicle, the emergency electronic brake light warns when vehicles several meters away is braking (Morando *et.al.,* 2018). Information about specific road conditions such as slippery roads can be received from several vehicles and used accordingly. Drivers receive such warning via a visual display, seat vibration or a tone. These are only timely warnings to help drivers respond quickly to avoid potential crashes. However, the driver has full control of the vehicle at all times. The V2V technology also provides drivers with 360^0 awareness of similarly equipped vehicles within a range of approximately 300 meters or 984 feet. V2V has a secure system which keeps personal information anonymous and does not support tracking of vehicles (Manish *et.al.,* 2019).

Vehicle-to-Pedestrian (V2P): The system uses a Dedicated Short Range Communication System (DSRC) to enhance pedestrian safety near roadways. The system consists of a DSRC platform in the vehicle and another in the smartphone the pedestrian will carry. With the V2P system, the safety of pedestrians on a direct line of sight and or crossing path, non-line of sight and backup positions are improved considerably to a great extent so that accidents are drastically reduced even if the pedestrian is not visible to the driver (Manish *et.al.,* 2019).

Once the range and trajectory fall onto the scope of the warning algorithm, a warning (brake light or beep) is displayed on the vehicle dashboard. The system also can mitigate accidents between motorcycles and vehicles.

Vehicle-to-Infrastructure (V2I): The system was built on three prior inventions namely the highway merge assistant and control (which enables vehicles at intersections and merging lanes to inform each other about their locations and velocity as well enabling negotiation between drivers), the on-board vehicle warning system (uses DRSC to enable drivers and vehicles communicate with their immediate surroundings to keep local laws), and lastly, the driver notification system (which alerts drivers of potential obstacles in the path of the car using data gathered via radio waves) (Manish *et.al.,* 2019). The V2I allows connected vehicles to receive key information from smart road network infrastructures such as the smart Traffic Management Centers (TMC). Road weather data are sent to Traffic Management Centers (TMC), providing detailed and real-time information to help monitor and manage transportation system performance. The TMCs in turn broadcasts current data about signal phase and timing and warnings. Critical weather information will appear on the in-car displays by dialling designated numbers. The TMCs provides real-time information about traffic lights, lane markings and signs, construction and school zones among others. Drivers can also receive a rail grid crossing alert which informs drivers of an oncoming train even if the driver cannot see the train coming. With the V2I system, vehicle idling and unnecessary stops are considerably reduced. Additionally, drivers can use provided information to adjust vehicle speed to pass the next traffic signal on green or slow down to a stop in an eco-friendly manner hence saving more fuel, reducing emission general cost (Idris, *et.al.,* 2018). Also, the V2I system enhances awareness by providing drivers with information about incidents ahead such as police activities, car crashes, disabled vehicles, first-aid activities. With connected vehicles, more lives are saved. Manish *et.al.,* (2019) state that V2I applications will not only be able to improve traffic safety, but also improve traffic efficiency and reduce congestion:

1. Red Light Violation Warning
2. Curve Speed Warning
3. Stop Sign Gap Assist
4. Reduced Speed Zone Warning
5. Spot Weather Information Warning
6. Stop Sign Violation Warning
7. Railroad Crossing Violation Warning
8. Oversize Vehicle Warning
9. Electronic Toll Collection
10. Pedestrian in Signalized Crosswalk Warning (PSWC)
11. Public transport priority
12. Traffic signal preemption for emergency vehicles

Vehicle Tracking

Today vehicle auctions and dealerships usually have large properties with thousands of vehicles on site. One of the rising IoT trends is exactly inventory solutions supported by the Internet of Things (Mustapha, *et.al.,* 2019). GPS trackers, which communicate with the local

low-power wide-area network, give dealerships the ability to track each of their vehicles. Those way salespeople can easily find the best vehicle for a customer. Tracking provides IoT managers with a more holistic and more granular view of their inventory.

On the other hand for the consumer, there could be many reasons they might need to know the exact location of their car. To easily find it in a massive parking lot for example or to find out if it was stolen. Automotive software developers are working on consumer-level tracking solutions (Manish *et.al.,* 2019). Soon car owners will be able to set limits and view a map that shows the vehicle's location. If the set speed limit or geographical boundaries are exceeded, the user will be notified on smart devices.

Maintenance (Preventative and Predictive)

The implemented sensors in the operational components of vehicles monitor their functional metrics like engine status, temperature, electrical systems, speed, and navigation. This also forecasts performance benchmarks. The gathered information is used to update vehicle owners with preventative and predictive maintenance alerts. This helps them to address issues before they even arise (Davika & Kumari, 2018).

Safety and Security

External sensors, such as rear-view cameras and proximity sensors take care of blind-spot detection and not only assist in easier parking but also safer driving. The advanced sensors protect driver's way more. They can monitor surrounding traffic patterns, as well as the environment to ensure safe driving. With the use of the new connected roadways, vehicles onboard systems can predict and avoid collisions for in advance of actual occurrences (Morando *et.al.,* 2018).

Real-Time Monitoring

Internet of Things allows real-time data sharing from vehicles to manufacturers. This could help with the improvement of maintenance and manufacturing processes throughout the vehicle's lifecycle. The real-time monitoring also helps for enhancing predictive insights, which allows faster response times in case of any serious issue. It makes manufacturers way more proactive in case of emergency (Morando *et.al.,* 2018).

Appraisal of the Need of Internet of Things in the Automotive Industry

After reviewing the application IoT to the automotive industry, this section appraises its applicability taking into cognizance the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The SWOT analysis is considered suitable when deploying IoT for the cyber-resilient automotive industry because analyzing the automobile industry is critical for the industry to make informed business decisions and uncover opportunities that they could exploit. A thorough understanding of the weaknesses enables the industry to eliminate threats that could otherwise catch them off-guard. Moreover, using the SWOT analysis framework helps automobile industries develop strategies that could distinguish them from competitors and gain a competitive edge.

Strengths: The automobile industry is witnessing a higher growth rate. It is offering people the opportunity to live, work and travel in unimaginable ways. Constant innovation is driving the growth of the industry and assisting the industry to address their declining profit margins. Such innovation entails the use of IoT and cybersecurity to move and developed economies due to cheap workforce and resources. For instance, According to Rodriguez (2017), the V2V transmitted messages common to all vehicles include:

1. GPS Position

2. Vehicle Speed Acceleration & Heading
3. Vehicle Control Information (transmission state, brake status, and steering wheel angle)
4. Vehicles Path History & Path Prediction

Similarly, Rodriguez (2017) also states that a few of the apps that may be available to help prevent car crashes include:

1. The "Do Not Pass" application: warns drivers when it is not safe to pass a slower moving vehicle.
2. The "Emergency Electric Brake Light" application: lets the driver know if a vehicle several cars ahead of you is braking.
3. The "Blind Spot" application: *(which for many may be the best part of this technology)* allows for drivers to virtually see everything that is happening in his or her blind spots.

Weakness: In the last few decades, the automobile market has transitioned from demand to supply market (Bjarnason, *et.al.,* 2014). The wide variety of options available in the market and stiff competition between companies has given the power to customers to decide whatever they like. Moreover, regulations such as excise duty, decreasing number of the validity of the registration period, and volatility in the fuel prices are a few of the major factors impacting the growth of the industry. IoT is still a fairly new concept and some weaknesses do exist. One is that there are concerns that devices from the automobile industry will not be able to communicate to one another, and steps may need to be taken to make sure that this is indeed the case (Liebel, *et.al.,* 2018). If not, individuals will be tied into one company's products, potentially, which may not be very satisfying for consumers. There may need to be one protocol developed that crosses country borders.

Opportunity: Optimization of fuel-driven combustion engines is offering a plethora of opportunities for companies in the automobile industry (Maurer & Winner, 2013). The changed lifestyle and customer groups and expanded regulatory requirements for safety are expected to increase the demand for fuel-efficient vehicles. Moreover, new markets like Asian nations will skyrocket the demand for vehicles. Opportunities are where it is really at with the IoT and why so many people are interested in investing in it. In particular, the IoT provides excellent opportunities for efficiency. This is already being delivered to some extent. For example, developments of RFID devices have allowed much better tracking of goods through the supply chain leading to less shrinkage for organizations. Other opportunities are less serious and highbrow but also likely to be very interesting to consumers are developments such as the recent announcement by Apple of "CarPlay". This allows the iPhone too, according to Andrew Dredge, take "charge of your car's infotainment system". Google is also reported to be doing this with Android (Pernstål, Magazinius, & Gorschek, 2012).

Threats: Threats to the Internet of Things may largely be grounded in people's fear of what technology can do. When you start raising the idea of robots communicating with one another and learning, the film I-Robot (or the stories developed by Isaac Asimov) spring to mind, where robots had been developed to the point that they were able to violate the Three Laws of Robotics and mount a coup against humans. Also, the concept that people might be able to control other people's minds using Internet of Things technology leads to concerns of control, as well as privacy arising. It is possible, and perhaps indeed likely, that such fears may

somewhat limit the development of the IoT while governments try to work out what is acceptable and what is too risky to develop. Of course, some might go ahead and develop anyway. On a lower level, privacy is already causing concerns with people worried about how much information devices may be able to collect about them and with whom and how that information might be shared (Maurer & Winner, 2013).

Conclusion

This paper covered a broad suite of issues that arise from the advent of disruptive technologies like IoT and cybersecurity. Besides, a holistic approach to an IoT based advanced automotive industry with a review of the main scenarios and the optimization strategies for designing and deploying these applications.

Recommendation

Based on the analysis, it was recommended that industries and academic institutions should be guided on the prospects of IoT on cyber-resilient automotive industry taking into cognizance the SWOT analysis.

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