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Low Power Wide Area Network Architecture for Detection of Traffic Signal and Pedestrian Crossing in an Autonomous Vehicle

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Abstract — *Automotive Industry is rapidly evolving and the next revolution is the autonomous vehicles. These vehicles will make mobility of human and goods safer and convenient. Autonomous vehicles sense the environment through various sensors and process the data for decision making. In this study the various surround sensors are studied in detail along with its limitations. As these vehicles need to meet the safety standard ISO 26262, this study also focused on the various external threats to the network devices, sensors and the associated software.*

In a road architecture there are two standard system available in a cross junction i.e. Traffic signal and pedestrian crossing. In this study a new networking technology i.e., Low Power Wide Area Network is proposed for autonomous vehicles which can efficiently predict the traffic signal and pedestrian crossing without any sensor embedded inside the vehicle. This technology can cover wide area in orders of kilometers and also uses very less power compared to available networking systems. This network uses an end device fitted in the signal and adjacent to pedestrian crossing sending signals to the gateway installed in the vehicle and further connected the end server. Experiment are carried out using LoRaWAN™ protocol in a virtual test bed environment to establish a connection between the end device and a gateway. The results prove that implementation of LPWAN technology is a safer solution than utilizing complex and costly surround sensor based system for detecting traffic signal and pedestrian crossing.

Keywords- *LoRa; LPWAN; Autonomous Vehicle; Computer Network.*

I. INTRODUCTION

Autonomous vehicles are considered as the next revolution in the field of mobility sector. Automobile manufacturers such as General Motors are actively investigating approaches for deploying partially autonomous automobiles, including vehicular formations driving under highway conditions referred to as ‘‘platooning.’’ Google has already developed driverless cars and the regulations for ADAS are being adopted in various states of USA. In a recent article published by IEEE, autonomous vehicle generally consists of 70 to 100 microprocessor-based ECUs, which control the engine, transmission, braking system, BIW, door, dashboard, tires, and heating, ventilation, and air conditioning (HVAC). In order to let a driverless vehicle, run autonomously initially it has to sense the external environment/surroundings followed by processing the data and act by making meaningful decisions. Currently sensing part of the external environment is taken care by sensors like camera, radar, LIDAR and referred as surround sensors. The two major sensory systems are described below and they are LIDAR and Camera based systems

A. Light Detection and Ranging (LIDAR) System

In order to navigate autonomously, self-driving cars requires precise localization within an a priori known map. To explicitly extract lane markings, traffic signs metadata is embedded into a prior map, which reduces the complexity of perception to a localization problem. [1] State-of-the-art methods (Levinson et al., 2007; Levinson and Thrun, 2010) use reflectivity measurements from three-dimensional (3D) light detection and ranging (LIDAR) scanners to create an orthographic map of ground-plane reflectivity. Reflectivity-based methods alone can fail when the road appearance is degraded over time or occluded by harsh weather and appearance based methods can fail when harsh weather is present in the environment. [2]

LIDAR is also used for pedestrian recognition by analyzing each image. Contour cues are used to detect pedestrians in crowded street, a joint detector is used to improve the detection result for pedestrians with partial occlusions. As compared with cameras, LiDARs can provide accurate range information and larger field of view. 3D point clouds are seen as a collection of several 2D point clouds at different heights, detectors trained by system such as AdaBoost are used to detect pedestrians. In 3D point clouds, the target is divided into parts, i.e., trunk and legs, to achieve robust in situ pedestrian recognition [3]. Both geometric and motion features are used to represent pedestrians, which deal with static and moving pedestrians.

B. Camera based vision system

Multi-camera systems, in general, have become important topics of research in the field of computer vision and computer graphics. Automotive surround view systems pose a particular challenge, because they are increasingly used to perform both scene visualization and computer vision tasks. Robust and reliable operation regardless of weather conditions and time of day is a critical requirement for vision based autonomous road vehicles. Research in the field of color constancy has produced a number of attempts to determine image features that identify the spectral properties of objects present in an image, regardless of the spectrum or intensity of the source illuminant.[4] A major challenge facing visual localization, navigation and scene classification approaches in outdoor environments is the change in appearance across a wide range of illumination conditions, in particular those encountered during a typical 24-hour day-night cycle. One of the latest methodology is the "Leuven/ Light" benchmark dataset for point feature illumination invariance which consists only of images taken from the same location with varying exposure.

II. LIMITATION OF SURROUND SENSORY SYSTEM

As cars will be driving autonomously on roads, functional safety assumes critical importance to avoid hazardous situations for humans in the car and on the road. Safety standard ISO 26262 is used to evaluate the safety level in an automotive system with QM rating being the least rating and ASIL-D is highest which is derived on the severity of the defect causing problem to human [5]. Limited or excessive data from the sensors and processing the same in order to make autonomous driving decisions may lead to erroneous output and is undesirable. This type of data collection may happen due to the inherent limitation of various surround sensors which is given below.

In radar based sensors the various information may not be in line of sight and if the identifying object is a nonmetallic object such as plastic or rock then reflection is a weaker signal. If the antennas are less than it may result in poor spatial localization. Radar also cannot detect visual information's such as traffic lights, signs. Lane marking and speed breaker. In vision based sensors the complex processing of data leads to increased software developmental cost. They are also sensitive to weather conditions such as rain, fog etc., and lighting condition in dark areas. Speed detection is difficult in vision based sensors. LIDAR sensors cannot detect traffic light, signs and speed breakers properly. They also have insufficient angular resolution at long ranges. The range of LIDAR is smaller than RADAR. Ultrasonic sensors are used for short range detection however they can be easily distorted by the reflections in the road. These sensors also don't have angular position and echo cancellation. Infrared camera is good for night conditions but have very poor contrast [6]. GPS or digital map is usually don't show the live conditions of the traffic light and they need to be connected to the internet.

III. HARDWARE AND SOFTWARE SECURITY

Embedded computing and sensor technology is explicitly used to enable complex networks of autonomous systems, such as robots, unmanned aerial vehicles (UAVs), self-driving cars, and unmanned underwater vehicles (UUVs) [7]. As with many of these complex networks of systems, it's possible for external intruders to intentionally compromise the proper operation and functionality of these systems. ECUs are connected using the CAN (controller area network) bus or FlexRay network. Autonomous vehicle possesses software consisting of over 100 million lines of code. By attacking the sensors or the software program, a malicious user can cause autonomous platform suicides and vandalism, as well as perform denial-of-service (DoS) attacks, and can even gain full control of the autonomous platform itself.

The opportunities offered by wireless systems also make them highly susceptible to various forms of malicious activities. Possible vulnerabilities aimed at vehicular communication systems and hardware are exploiting standardized wireless interfaces for DoS attacks and eavesdropping via wireless side-channel attacks. Engineers have analyzed various embedded computing system and sensor based weakness on cars, which can be accessed by nonconventional methods such as the music system or pressure sensors implemented in tires. Besides the common security requirements like privacy, confidentiality, Distributed Denial of Service (DDoS) protection and authentication, the AUV is very vulnerable to vicious attacks that may disable the steering or the brakes system.

IV. AUTONOMOUS VEHICLE NETWORK

Autonomous cars are coming and they need to be safe in order for wide acceptance of this technology. There is no one solution which will make autonomous cars safe. Multi-sensor fusion and distributed HW architectures can make sure there is no single point of failure which causes hazardous situations for humans. SW architectures using frameworks like OpenVX can help implement multi-sensor fusion on distributed HW architectures. Finally, real-time HW/SW monitoring and diagnostics need to be deployed to make sure the system behaves according to specification. An autonomous vehicle typically uses sensor fusion architecture but still the importance of multiple sensors having redundancy remains high to allow a better decision from a fusion algorithm. Automated vehicles require robust localization algorithms with low error and failure rates.

In order to communicate and cooperate with each other, standard software and hardware platforms are essential. AUTomotive Open System Architecture (AUTOSAR) is a standardized software architecture in the automotive industry. LIN, CAN. FlexRay, and MOST are developed for the in-vehicle network of cars [8]. FlexRay, which is the next-generation in-vehicle network in the automotive industry, is applied for the backbone network of the system platform in order to increase network bandwidth, fault tolerance, and system performance. One of the main challenge in FlexRay is that there are several commercial tools for configuring FlexRay that check fault configuration based on the parameter value constraints in the FlexRay protocol specification. However, the tools do not provide optimal parameter configuration for optimal network utilization because the optimal configuration is a difficult problem to solve due to the over 70 parameters and the complex relationships

V. LOW POWER WIDE AREA NETWORK

The autonomous cars are instrumented with numerous surround sensor system which can generate tons of data at each minute. At the same time, the road is instrumented with smart components, RFID tags, and embedded microcontrollers. These Things constitute a Vehicle Grid, i.e., an intelligent road infrastructure analogous to the energy grid for intelligent power generation and distribution [9]. This will lead to the emergence of the Vehicular Cloud. Recent advances in communications, controls and embedded systems have changed this model, paving the way to the Intelligent Vehicle Grid. The next step in this evolution is just around the corner i.e. the Internet of Autonomous Vehicles. However, the complexity of the distributed control of hundreds of thousands of cars cannot be taken lightly. In case of a natural disaster such as fire or quake then vehicle should be able to coordinate among its system and outer environment via networks and start evacuation in an orderly manner.

The DSRC dedicated spectrum, in principle, can support the V2V traffic, or at least the traffic for beacons and emergency services. In today's age of rapid growth of safety communication platforms, it is expected that the DSRC 75 MHz spectrum will be quickly exhausted. Although the general requirements of the next generation of communication systems, generally referred to as 5G, are still being debated by industrial and academic experts. Radio frequency identifiers, short range wireless communication technologies such as Bluetooth and wireless sensor networks are regularly used in IoT applications. The limitation with all the above technology is that either they have limitation in terms of distance, they consume huge power, they create congestion in the network traffic and are generally complex and costly.

A novel networking technology referred to as Low Power Wide Area Network (LPWAN) is considered as one of the potential solution to the autonomous vehicles [10]. This technology falls in between short-range multi-hop technologies and proper broadband cellular systems. Similarly, to the cellular networks, LPWAN technologies are characterized by long- range links (in the orders of kilometers) and have star network topologies, LoRaWAN™ is one of the solution which works in LPWAN principle and LoRa works on wideband and sub-GHz range. Refer Figure 1 for the LoRa protocol architecture. LPWAN is designed for battery operated sensory system which can be stationary or moving with the product. This network typically is laid out in a star-of-stars topology in which gateways relay messages between end-devices and a central network server at the backend. The data rates range from 0.3 kbps to 50 kbps in this network [11].

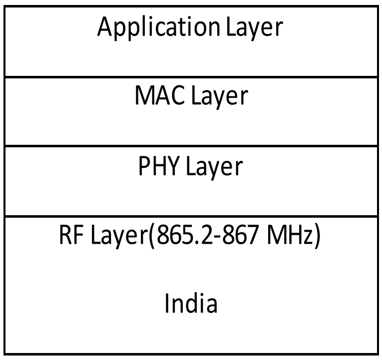


Fig 1. LoRa Protocol Architecture

There are totally three MAC Layers I.e. Class A, B & C. Refer figure 2 for LoRaWAN layers. One of the limitations of LoRaWAN Class A is the Aloha method of sending data from the 8 end-device it does not allow for a known reaction time when the customer application or the server wants to address the end-device and thus Class B is a preferred protocol for autonomous vehicles [12]. In this paper class B sensor is used to detect particular road condition i.e. Traffic Signal and Pedestrian Crossing. It is intended for end-devices that need to receive commands from a remote controller, e.g., switches or actuators, or need to provide data at user's request. The sensors are expected to possess Class B operation as and when there is a need to open receive window at time intervals for the target of starting server initiated downlink messages. This option also adds a synchronized reception window on the end-device. Class B is achieved by having the gateway sending a beacon on a regular basis to synchronize the all the end devices in the network so that the end-device can open for a short extra reception window (called —ping slot‖) at a predictable time during a periodic time slot.

Application		
LoRa MAC		
MAC Option		
Class A	Class B	Class C
LoRa Modulation		
ISM Band		

Fig 2. LoRaWAN Layers

VI. METHODOLOGY & RESULTS

In this experiment Gateway is established into autonomous vehicles. Signals are received from sensors in the form of binary code as 0,1,10 respective to red, orange and green signals. The vehicle will act according to the signals. LoRa transceiver is mainly used to sense the signals. The Things Network is used as the network server to control end nodes i.e. traffic light and pedestrian crossing and gateway. A Gateway is developed by using RaspberryPi3 Model B equipped with a HopeRF RFM95 LoRa transceiver chipset for 867 MHz ISM band. RaspberryPi3 Model B is equipped with Wi-Fi connectivity. Two Gateways are proposed to be created at Location 1 and at Location 2 at a distance of 10 Km. Sensors collect signals and Traffic rate is analyzed using it. Refer Figure 3 for the system architecture to detect traffic signal and pedestrian crossing. It is configured with ABP parameters and its software based on class B protocol. Gateway supports single channel and uplink messages. Gateway listens to the channel with preconfigured frequency and SF values. The distance measurement is carried out using HCSRO4 sensor and traffic signals are simulated using LED lights. Refer figure 4 for the output when Raspberry Pi is used to act based on distance and lights and raspberry is also connected to power module. Experiment was analyzed independently without any interruption and external intervention. All experiment is performed using a single channel in a non-noisy virtual test bed environment.

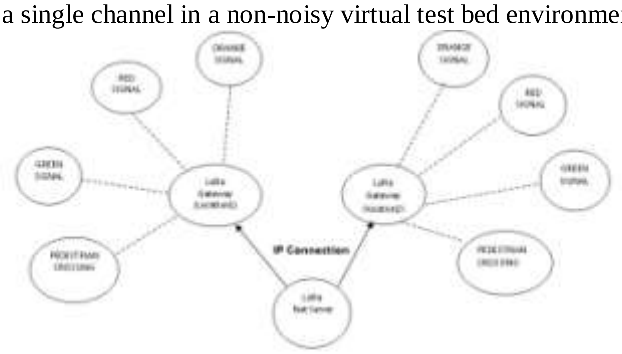
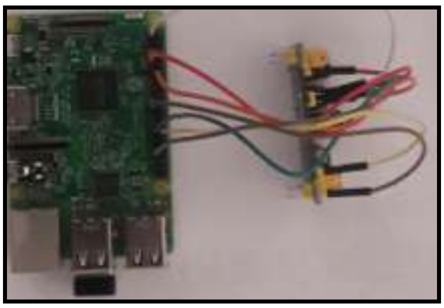
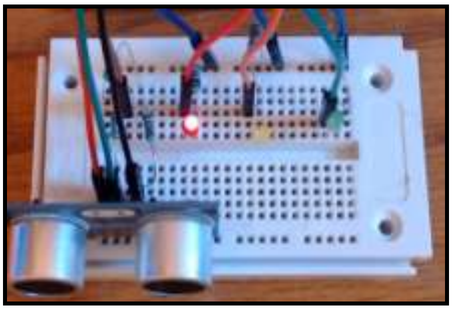


Fig 3. System Architecture for Traffic Signal and Pedestrian Crossing Detection



a



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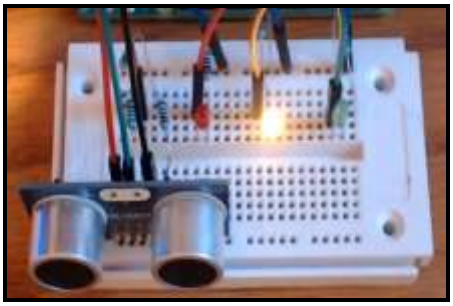

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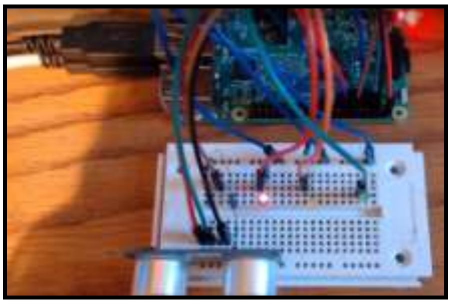

d

Fig 4 a) Raspberry Pi connected to the Power Module. b, c & d) Traffic signal simulation using LED and distance sensor in virtual test bed environment

VII. CONCLUSION

In this study the study was focused on autonomous vehicles. The various surround sensor system is studied in details and its various limitation with respect to its through put is explained. The safety of the vehicle is highlighted and its requirement to compliance to ISO 26262 is explained. Considering the various threat by the external intruder on the sensors and networks within the vehicle and considering the complexity and high cost of the sensor system currently used to detect various road architecture is given. A novel networking technology based on low power wide area network is proposed to be implemented in the autonomous vehicles wherein the sensor will be fitted in the end device and a single gateway will collect data for further decision making. LoRaWAN Protocol is used and experiments were conducted in a test bed environment with distance sensor and led lights to simulate the real-world environment. This technology is possible as it consumes less power and has a range in kilometers with affordable prices as compared to other networking technology such 3G/Wi-fi. In the future further experiments will be carried out along HOPE RFM95 radio module [13] and a single channel gateway connected to the things network. Technoeconomic feasibility for implementation in actual vehicle will also be carried out.

VIII. ACKNOWLEDGEMENT

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IX. REFERENCES

[1] Ryan W. Wolcott, Ryan M. Eustice "Robust LIDAR Localization using Multiresolution Gaussian Mixture Maps for Autonomous Driving", IEEE International Conference on Robotics and Automation, Seattle, WA, USA, 2015
[2] Brent Schwarz "LIDAR Mapping the world in 3D" Nature photonics, VOL 4, JULY 2010
[3] Heng Wanga, b, Bin Wangb, Bingbing Liu b, Xiaoli Meng b, Guanghong Yanga "Research Pedestrian recognition and tracking using 3D LiDAR for autonomous Vehicle", College of Information Science and Engineering, Northeastern University, Shenyang, China Institute for Infocomm Agency for Science, Technology and Research, Singapore 2016
[4] Will Maddern, Alexander D. Stewart, Colin McManus, Ben Upcroft, Winston Churchill and Paul Newman IS&T "Illumination Invariant Imaging: Applications in Robust Vision-based Localisation, Mapping and Classification for Autonomous Vehicles", International Symposium on Electronic Imaging 2017, Autonomous Vehicles and Machines 2017
[5] Kedar Chitnis, Mihir Mody, Pramod Swami, Sivaraj R, Chaitanya Ghone, M G Biju, Badri Narayanan, Yashwant Dutt, Aish Dubey "Enabling Functional Safety ASIL Compliance for Autonomous Driving Software Systems", Automotive Processors, Texas Instruments, 2017
[6] Vladimir Zlokolica, Brian Deegan, Patrick Denny, Mark Griffin, Barry Dever, Valeo "Free-view multi-camera visualization and harmonization for automotive systems", International Symposium on Electronic Imaging 2017 Autonomous Vehicles and Machines 2017
[7] Alexander M. Wyglinski, Xinming Huang Taskin, Padir Lifeng Lai, Thomas R. Eisenbarth Krishna Venkatasubramanian "Security of Autonomous Systems Employing Embedded Computing and Sensors", IEEE Computer Society
[8] "Development of Autonomous Car—Part I: Distributed System Architecture and Development Process" IEEE Transactions on Industrial Electronics, December 2014, DOI: 10.1109/TIE.2014.2321342
[9] Mario Gerla_, Eun-Kyu Lee, Giovanni Pau_z and Uichin Leey, "Internet of Vehicles: From Intelligent Grid to Autonomous Cars and Vehicular Clouds"
[10] Vangelista, Andrea Zanella, and Michele Zorzi "Long-range IoT technologies: the dawn of LoRaTM", Proceedings of the 1st EAI International Conference on Future access enablers of ubiquitous and intelligent infrastructures (Fabulous 2015), Sep. 23-25, 2015
[11] LoRa Specification, 2015 LoRa Alliance.
[12] Claire Goursaud, Jean-Marie Gorce "Dedicated networks for IoT: PHY / MAC state of the art and challenges", EAI Endorsed Transactions on Internet of Things, Volume 1, Issue 1, 2015
[13] RFM95/96/97/98(W), Low Power Long Range Transceiver Module V1.0