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REVIEW ON RANGE OF CONTROLLER AREA NETWORK (CAN) PROTOCOL IN DIFFERENT AUTOMOBILE APPLIANCES

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ABSTRACT

Controller Area Network (CAN) is most proficient and reliable proposal for automobile applications. This paper enlightens the history and factorization of CAN protocol in vehicular based network environment. Hence, the review presents brief outlook of CAN Protocol attainments in various hardware like processors and all other connected peripherals and software. This study paper will give detailed usage of networks in automobiles for technological evolution on CAN protocols.

Key Words: TTCAN, Software-Defined CAN Controller (SDCC), CAN Open and CAN-FD

1. INTRODUCTION

Controller Area Network Protocol (CAN) is an effective communication mechanism developed by Bosch in 1980s. CAN is mainly designed for serial communication with multi-master bus which facilitates each node in the network [1]. It specifically operates within noisy environment of control system for electronic units and parameters. CAN serial bus is proposed with fast transmission speed (up to 1 Mbit/s). CAN acts as transmission protocol which is message oriented. CAN is ISO Standard protocol which illustrates the way, messages are passed between the devices [2]. This message in network conforms to the Open Systems Interconnection (OSI) model that is defined in terms of layers [3]. The Controller Area Network (CAN) is a protocol which communicates serial information with distributed real time control, also leads the network in cost effective manner [4]. This protocol provides broadcast mechanism where all messages are transmitted with an identifier (only content o the message). CAN communication medium contains two-wire bus line which offer high level security [5]. Efficiency in cost leads to construct the Electronics Vehicle like lamp clusters, electric windows etc. to substitute required wiring harness [6]. Application of CAN Protocol varies from range of all high speed networks to low cost multiplex wiring[7]. Major application of CAN is automotive electronics where engine control units, sensors, antilock braking systems and many more are connected using this protocol with maximum bit rates [8]. Compatibility of CAN is achieved by dual CAN implementation with different aspects of (example) electrical features and data interpretation (to be transferred) [9].

The CAN bus presents different modules of interconnection where each module communicates with each other under the ideal platform. It is also used in higher data integrity networked system for fast and robust communication[10]. Robust nature of CAN Network allows sophisticated error detection and prevention, also errors and failures in the network occurs without affecting the entire system (shutting down the system)[11]. This error handling capacity of CAN is useful in the motor control node[12]. Installation and utilization of CAN Network is simple and inexpensive circuitry, above which every sensing unit and actuating unit [13] are equipped with a CAN interface (applications like automotive and industrial automation) [14].

According to ISO Open System Interconnection, CAN protocol are categorized and developed based on OSI layer model (seven layer model). Considering OSI layer model, CAN Protocols are urbanized using three layers which are Physical Layer, Data Link Layer and Application Layer. Many extended CAN Protocols are based on above layers for enhanced characteristics for diverse end applications. CAN communication protocol is implemented to a great extent for its high reliability and performance in harsh environments. CAN network is accessed in automotive and automobiles, industry automation, Military and Defence Residential and etc. Foremost application is Automobiles where parametric revolutionize and forthcoming technologies of CAN are designed in vehicular network. The main objective of this paper is analysis and study of CAN Bus network in vehicle application. This paper is organized as follows: Automobiles and Vehicular network as Section 2, Summary of CAN Development as Section 3, Conclusion as Section 4 and References as Section 5.

2. AUTOMOBILES AND VEHICULAR NETWORK

European-funded projects like SEVECOM, PRECIOSA, EVITA, and OVERSEE have conducted studies on vehicular security actively for last fifteen years. The policy released by National Highway Traffic Safety Administration (NTHSA) based on Vehicle Automation was developed in 2013. There are five levels of Vehicle Automation defined by NTHSA in which level0 having no automation and level4 being a full self-driving vehicle. International Standard J3016 was released in 2014 by the Society of Automotive Engineers (SAE) which led six levels of automation in driving. In this Level0 defines no automation through Level5 which defines full automation. Autonomous vehicle by Google was probably known since its commencement in 2009. Other well known manufacturers in automation like Mercedes Benz, Delphi, Audi, Nissan, and Bosch, have been researching various aspects of autonomous driving till date. The Victoria Transport Policy Institute provided vision on research of Vehicle Automation, by which they suggested that fully self-driving vehicles will be commercially available after 2040 [15] .

Samuel Woo et al., describes the CAN bus data of automobiles usually described by algorithm was implemented on Python Programmable language with Linux box using a USB2CAN adapter with eight different devices and also in C# software language for Windows machines where CAN adapters are fixed with USB. CAN bus based on Vehicle and Simulation-based systems were at risk in capturing and rerun of the messages in CAN bus [15].

Sheher Banu et al., provided 80% of solution for collision free driving using CAN. CAN standard chiefly designed for vehicle development provides exchange of data between each controller based devices [16]. Critical data by the system is sent as an alert to the driver regarding impediment nearing the vehicle which tend to slow down the vehicle automatically with sufficient time for corrective action taken by driver. Hardware and software components are used to fulfil the requirements, which utilizes ARM 7 LPC 2129 processor known for speedy reaction time and powerful and proficient control reaction [17]. Obstacles nearer (based on distance) to the vehicle are detected using an ultrasonic sensor. The distances are segregated by optimization in three different ranges, 0 to 20cm, 20 to 35cm and 35 to 300cm. This above framework has favourable circumstances over reaction time and independency of outer situation, but its expense and dependable in real environment. Reconsideration of this framework with control activity of CAN arrangements may stay away from collision and along with its diagnostics, it can lead to a better real time ability [16].

Govindaraju et al., proposed main concept which is to operate the vehicle speed at critical zones at safer side. The base station having the transmitter and receiver corresponds to base station which is designed for Frequency Modulation (FM) and implemented in Vehicle respectively using CAN bus adapters. Software that is used for the developer to support the system is Keil C. Compatible derivatives used in the system are Keil C compilers which is industry standard, Macro assemblers, Debuggers, Real time kernels, and single board computers support, helps the project to be completed on time. The Keil tools can generate embedded based applications for virtually every ARM processor. Here in this proposed system Keil C vision 4 is provided for various simulation output. This paper presents an effective solution for intelligent vehicles that was developed to operate on safest speed at all critical zones and also to monitor various parameters of vehicle at constant time interval which are sent to the base unit. Thus alerting the driver about the speed limits[18] and detecting the critical area are done in place of automatic control [19].

Manuele Bertoluzzo et al., analysed the limitations of CAN and has provided two protocols as solutions: time-triggered (TT) protocols and native CAN with ad-hoc developed application protocol. The protocol, termed TT bus-redundant CAN (TTBR-CAN) is built up around the Time triggered concept and bus redundancy. CAN network has a structure where each node is connected and is collectively asembled by the bus driver (BD), the communication controller (CC) and the host controller (HC). Pair of wires in the CAN Bus denotes CANL and CANH, which transmit the bits encoded in terms of differential voltage values. The Controller Area Network (CAN) bus serves as a legacy protocol for in-vehicle data communication. Simplicity, robustness, and suitability for real-time systems are the salient features of the CAN bus protocol. However, it lacks the basic security features such as massage authentication, which makes it vulnerable to the spoofing attacks. In a CAN network, linking CAN packet to the sender node is a challenging task. This paper aims to address this issue by developing a framework to link each CAN packet to its source [18]. Thus the transmission medium of CAN is formed by high-level transmission line CANH and low-level transmission line CANL [28]. Event-triggered (ET) paradigm for the message transmission utilized by Native CAN, i.e. external event as CC is used to send a message, for instance by an HC request.. Anticipation is not accessed due to non-deterministic CAN in state domain in which the node accesses the bus only at a given time instant and the type of message is transmitted. Native CAN is fault bounded. Triggering and SYNC Special message achieved by CANOpen FlexCAN architecture requires running of a redundant bus by means of the TT paradigm and the CAN application protocols like Flexible TT (FTT)-CAN and Fault-Tolerant TT (FTTT)-CAN. Both bus redundancy and the node redundancy are supported by FlexCAN architecture. TTBR-CAN tolerates a bus fault an overloading in HC. Thus this paper provides novel of CAN application protocol with performance of the existing ones in time determinism and processing time [14].

Gedare Bloom et al., proposed concept performing an Exclusive Nor (XNOR) operation with special function called binary Boolean function. This function is carried out conveniently on the bus by means of CAN XR. CAN XR allow concurrency by multi node to transmit within the data field of the same bus *transaction* and arbitration, as standard performance of CAN. The Physical layer of CAN has two complementary bus states called *recessive* (1) and *dominant* (0). The setup used for the evaluation consists of Three CAN nodes are one initiator/responder, one responder and one consumer used for step up evaluation here two nodes are implemented by means of a software-defined CAN controller (SDCC), extended to support CAN XR . This paper demonstrates backward compatible of CAN XR and extension of the CAN data-link layer to calculate arbitrary binary [20].

Pallavi et al., discussed about the implementation of the CAN 2.0 A/B in Vehicle Electronics. The On-board diagnostics (OBD) was created for automotive based research, but most common application in recent years are in vehicle electronic diagnostics. This above process of communication can be handled using extremely robust packets called messages. OBD connector is used here to fix CAN bus is with diagnostic tool. The two versions of CAN Protocol are supported by PICI8 ECAN module which are CAN l.2, CAN 2.0A, CAN 2.0B Passive and CAN 2.0B Active versions, also master slave communication implemented through CAN protocol in On-Board diagnostic. PICI8 microcontroller is used for both master and slave communication platform. The modules in PICI8 are as follow as 32 Kbytes program flash memory, 10 bit ADC with up to 8 channels and Enhanced CAN module. In this paper two types diagnosis (on-board diagnosis and off-board diagnosis) are used for monitoring engine parameters. The CAN 2.0B protocol is used here in diagnoses for designing diagnosis system efficiently which are achieved up to 1 Mbps data rate.
The ADC modules used for various Sensors and data flow rate are represented into the OBD by ADC Modules with updated at timing. Software used in this proposed diagnosis is embedded C code for CAN 2.0B protocol and tested in CANKing software [1].

Santhosh Kumar et al., proposed work, where each measure are converted into two modules as master module and slave module. The proposed automatic front headlight adjustment system is done by master module consist of LPG gas leakage sensor, Exhaust gas control unit and Temperature monitoring unit. Other sensors like digital fuel level sensor, short-circuit identification unit, wheel pressure monitoring sensor and Radio Frequency transmitter and receiver are used for horn volume automatic adjustment in Slave module [21]. Double layer PCB is designed for above sensor management in the master and slave of CAN Module. This proposed system are achieved with hardware platform like Surface Mount Device Hardware [22]. The Controller Area Network communication between master and slave are achieved with high reliability. This paper also projected cost effective and improved network speed of 1 Mb/s, with excellent error detection, confinement capabilities and reduced hardware size. Hence the above all process in this proposed system and CAN protocol, along with various sensors provided effective safety measures in automotive vehicles [23].

Chung-Wei Lin et al., proposed a paper to prevent cyber-attacks like masquerade and replay in vehicle architecture based on Controller Area Network (CAN). In this paper, security mechanism keeps tracking the utilization of bus network , which helps to maintain (bus utilization) as low as possible [24]. In case of any attacker into the network the receiver cannot verify the identity of the sender of the message , since the same attacker could have pretended to be someone else (by sending a message with an ID and pretender cannot configure to send in the first place) called as masquerade leading to possible “replay” attack (attacker) [25]. As the attacker pretends to be someone else, this above scenario leads replaying verbatim of same message it has received (which is not entitled). Since CAN is a broadcast protocol, both a strong and weak attacker can be successfully carried out into the vehicular network. In absence of security mechanism, masquerade/replay attack can be carried out between sender and receiver. Thus pairwise keys are used as the attacker which would not lead the attacker to successfully carry (attack) on the CAN bus network. The main concept of this proposed security mechanism is that each node carries the mechanism to avoid attacks in the system. Hence mechanism is highly suitable for CAN protocol due to its low communication overhead and does not need to maintain global time [24].

Generally all Automobile application offers the communication standards between different Electronic Control Units on vehicular network [26]. Xiang Zhang et al., discussed about CAN protocol which does not consider some of the security issues like authentication and access control, therefore algorithm related to attacks can be implemented into it. Thus the process leads more efficient protected communication system in appliances. Nowadays, Car manufacturers started improving safety of their automobile system by employing all traditional security mechanisms. Security mechanisms include features like system lock-down, security hardening, encryption, etc., on ECUs to prevent compromised way of marketing. But above approaches alone cannot hold attacks from the OBD-II. This is a legislated required for interfacing all kind of direct communication to CAN bus. The key insight underlying this proposed approach is that the transmission of malicious messages cannot only be detected and also prevention is performed before transmission on CAN bus [27]. The problem here is addressed by introducing an effective method called runtime verification method. In this approach, runtime verification framework is mainly used for real-time systems which is most popular framework is called as *Copilot*. *Copilot* is dataflow language (stream based dataflow language) which can be assembled into constant time and constant space of C based monitoring programs. OBD-II port is used in most of all automotive industry for diagnostics on vehicles through CAN network, likewise in this proposed technique it is used for diagnostics. Runtime attack defending framework for Controller Area Network is called as RdCAN, which is generated from monitors of Copilot. It can also be referred as specifications .Thus the proposed basic idea of RdCAN is to implement runtime monitors, which scrutinize the exchange of message with all interconnects like ECU and OBD-II port [26].

CAN is strong protocol which diminishes the utilization measures for the interconnections, approach defines conventional CAN which is an innovative serial communication correspondence to convention which takes fault containment after ISO 11898 model [28]. This generally acknowledged in cars because of its following characteristics like constant execution, unwavering quality and correspondence with extensive variety of gadgets [29].

Ashwini S. Shinde et al., proposed design and implementation of CAN Bus prototype in ARM7 Processor for vehicle automation. This automation technique spotlights on both hardware and software to design nodes with all intelligence. Interfaces in hardware circuit mainly consists of MCP2515, LPC2148 microcontroller (based on 32-bit ARM7) TDMI-S CPU and MCP2551 [30]. MCP2515 and MCP21 are stand alone CAN-Controller with SPI interface and high speed CAN Transceiver respectively, where MCP2551 implements requirements of ISO-11898 standard physical layer requirements [31]. This proposed software design is implemented for CAN bus network to design CAN bus data communication and data processing for analog signals between nodes. This design consist of software design communication module which comprises system initialization unit, CAN controller initialization unit, message sending and receiving unit and the interrupt service unit [30].

Tejal Farkande et al., developed CAN to employ cost effective communication bus in cars. Thus above communication protocol replaces following features like expensive, cumbersome and unreliable wiring looms and connectors in high end cars. This paper also presents successful extraction of CAN messages from automobile ECU's. The Extraction is performed by building hardware and software, also projects interfacing and communiction directly with embedded CAN network. Implementation of this process give rise to extracted CAN messages which is used for communication in automobile ECU's. The above data will help user to keep updating concurrent status of automobile system [32].

J. Novák et al., described computability with hardware and software, stating that CAN protocol has detection of errors in the received data. This detection is performed by four detection mechanisms [33]. Samuel Woo et al., *derives* an attack model using a malicious smart-phone application. This proposed attack model processed in the connected car environment are demonstrated practically on research. Thus security protocol in the paper designed and applied to the car environment with an analysis of the vulnerability of in-vehicle CAN [15].

Supriya Kelkar et al., proposed new algorithm called as adaptive fault diagnosis algorithm for CAN (AFDCAN).This is mainly designed to build distributed embedded systems of low-cost and resource-constrained. This adaptive algorithm identifies all kind of faulty nodes on the CAN network, also allows new node way in and re-access of respected node with renovated faulty nodes. Faulty nodes are repaired during a diagnostic cycle. AFDCAN offers high fault tolerance and reliable communication which is utilized in solitary channel (single channel) communication. These are performed by organizing the bus-based standard CAN protocol. Thus kelar et al., showed that this adaptive algorithm diagnoses most of the faults in the system. [34]

Tulasi et al., proposed CAN Protocol is used to monitored the parameters with necessary control made for each parameter. The Carbon Monoxide (CO) concentration is maintained (below 300 pp), to avoid breathing disability inside the vehicle. The diverse parameters are monitored using sensors, which can be noticed by the driver in LCD. The parameters are prioritized with close loop control. CAN bus energise the boom of automobile techniques by reduced complex wiring and speedy data transportation with greater flexibility. These features in CAN bus makes its uses very essential in networking bus of automobile vehicles for communication. This paper uses ARM 7 processor which ensures low cost and power, high efficiency, fast operation and higher performance [35].

Manchireddy Divya et al., proposed concept based on implementation of CAN bus on automated vehicles. Here, RX62N microcontroller (Hardware Component) is use to test CAN Protocol. This paper proved the compatibility of CAN Protocol which ensures its implementation in any of embedded systems. Thus paper proposed Vehicle with CAN for real time transmission of data (less number of interconnectivity) and large number of devices to communicate are achieved [36].

Vinodh Kumar et al., implemented strategies of automotive deals with short messaging scheme and selective bit stuffing method to improve the effective utilization of network bandwidth. This paper presents a work on short CAN technique for effective utilization of available CAN bandwidth. It also discovers the impact of selective bit stuffing over data payload without any major change in the existing CAN protocol. All the above performance are examined in Simulink working model simulation and real time CANoe hardware with multi functional display proving bandwidth utilization [37].

Ashish Prabhakar Patil et al., implemented CAN protocol for data acquisition in vehicle monitoring using LPC1768 ARM Cortex-M3 processor [38]. The difference between the current message and preceding message is transmitted in active CAN data compression technique [4]. The Redundant flag codes are used in this active CAN data compression technique. Generally Active CAN data compression method the space saving is 12:5 Percent and compression ratio is 1:14, but in Proposed method the space saving is 62.5 and compression ratio is 2.67 Percent. Thus data is reduced up to 50 Percent in the proposed method which can be used in automobile application for effective utilization [38].

Kalaiyarasu et al., proposed paper which describes CAN Protocol by communication of two modules called Master and Slave. The functions like gas leakage detection with protection and temperature monitoring function are present in Master module. Other facilitators like Automatic Front Headlight Adjustment system (AFHAS) and short circuit fault line indication function are present in Slave module. The SMT (Surface Mount Technology) with SMD (Surface Mount Device) components are used here to develop hardware with double layer PCB (Printed Circuit Board) design to optimize the space requirement and power consumption. The proposed system provides cost effective safety system with reliable connected networks [39].

Eunmin Choi et al., proposed turbo Controller area network (TURBO CAN) to provide highly reliable backward compatibility. Here, network contains standard CAN system dealt by channel capacity and BER analysis. The channel capacity analysis of this system were measured with standard CAN bus in real time car environment. This paper also resolves noise characteristics out of the above analysis. Water-filling power allocation scheme is used here to determine the upper bound frequency and lower bound frequency bounds for channel capacity of the TURBO CAN. Thus this process proved that TURBO CAN system can highly attain more than 1 Gbps , even under the worse channel conditions [40].

3. SUMMARY OF CAN

Table 3.1: Different Categories of Protocols and Features In-Vehicle Communication

Features (During Broadcast)	***CAN***	***LIN***	***FLEXRAY***	***CAN-FD***	***FTT-CAN***	***MOST***
Messaging and Data Type	Event Triggered	Event Triggered	Event Triggered And Time Triggered	Event Triggered And Time Triggered	Event Triggered And Time Triggered	Event Triggered
Maximum Data Rate	1 Mbps	10Mps	19.2Mbps	16Mbps	100Mbps	150Mbps

Table 3.2: Categories of Extended CAN Protocols

Categories of CAN	**ISO Standard**	**Physical Layer based characteristics**	**Data Link Layer based characteristics**	**Application Layer based characteristics**
Classic CAN	ISO 11898-1	Short stubs with	Payload is 8byte	Error detection and

		twisted pair cable Data Transfer is only up to 1Mbs		correction with CRC-8bit
TT CAN	ISO 11898-4	Topologies with time master frame. Data faster than 1Mbs	Two level of data types	Error detection interrupt resources
CAN FD	ISO 11898-1	Line and star combined topologies. Data faster than 1Mbs	Payload is up to 64Byte	Even Single failures are detected under all conditions(CRC field 17bit or 21 bit)
CANOpenFD	ISO11898-1:2015	All types of topologies with hybrid protocols. Data Transfer is only up to 5Mbs	All used data types	Comprehensive Diagnosis (Error frames with time stamp)

4. CONCLUSION

Application of CAN is predominantly experienced on automobile and Vehicular Technology. CAN protocol can also be implemented in many other domains are reassessed for controlling more than one node to form effective network. The CAN bus network is optimizing for all products of transmit and receive mechanism of relatively small amounts of information, and its reliably communicated to any other nodes on the network. Fast and robust message transmission with fault confinement is also provided in this protocol. Automatic dropping of faulty nodes effectively guarantees that bandwidth will always be available for critical messages to be transmitted [34]. These benefits built into the CAN protocol with very minor constrains in the automotive world, will promote CAN and its implementation in all other forthcoming technical network development.

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