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CAN Based Unified Customizable Diagnostic Measure Research And Realization

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Abstract— **To diagnostic vary CAN bus based network, an unified customizable diagnostic measure is introduced. The measure is based on customizable RPN format protocol expression and CAN UDS, support most of CAN bus based network. Not only decoding or other normal diagnostics are supported, but also network activity is analyzed, too. Furthermore, the design of customizable diagnostic software is given.**

Keywords-UDS;RPN;CAN bus Diagnstics;ISO 14229

I. Introduction

CAN based fieldbuses have been used for years and different upper application protocols were produced, such as CANOpen, ISO Bus, SAEJ1939 and DeviceNet, and so on. To apply and maintain those fieldbuses, protocol analysis tool are overwhelming needed. Early detection of network failures and performance degradations is a key to rapid fault recovery and robust networking [1]. Though fieldbus mentioned above are based on CAN bus, the great gap between their application layer make it was very difficult to diagnostic all of them in one application platform. Automotive network ECU manufactured by different vendors is different [2], so a unified customizable diagnostic tool is important to auto diagnostic, too.

CANOE or other software can do this job but the huge invest and not very clearly decode explains are the fatal weakness. There are vary diagnostic tools exist in the CAN bus application. Different diagnostic tools lead to more development and maintenance cost, and for some scenes it is too inconvenient.

In road vehicle application scope, a series of Unified Diagnostic Services (UDS) standards have been made by ISO, its purpose is to make diagnostic more convenient and less development repetitious. ISO 15765 and ISO 14229 have achieve CAN based UDS[3], there should be only one diagnostic protocol theoretically, but it is applied almost only in vehicle area in fact. The CAN based UDS most likely can be used in vehicle-related application scenes.

A CAN based customizable diagnostic method (CCD-Measure) is introduced in this article, furthermore, a customizable diagnostic tool aim on CAN based fieldbus is realized. This CAN bus based customizable diagnostic tool (CCD-Platform) support ISObus, SEAJ1939[4][5], CAN UDS, etc., the most significant is customizable application layer analysis function. Any CAN based protocol nevertheless normal or private can be decoded, explained and analyzed well. Only if a clear definition is provided.

II. Unified Diagnostic Meature

CCD-Measure introduced in this article is customizable and support CAN UDS, the former make it is possible that CCD-Platform can be used in non-vehicle area such as CANOpen, DeviceNet, meanwhile the latter make sure that most newly designed road vehicle ECU and network can be analyzed and diagnosed by this platform.

A. CAN Bus based Unified Diagnostic Services

CAN UDS is proposed in two related standards, ISO 15765 and ISO 14229. It is designed for road vehicle diagnostics, but it can be used in other area such as farm machinery, construction machinery, etc. Some ECU (electronic control unit, a control device on vehicle bus) manufactures has support the CAN UDS such as Bosch, Perkins and so forth. CAN UDS is an independent upper protocol, support 25 services including “ECURese”t, “TesterPresent” and “ReadDataByIdentifier”, etc. ISO 14229 is an “application layer” in the UDS architecture and ISO15765 part 3 is a simplify version of ISO 14229, both of them define the diagnostic services.

TABLE I. CAN UDS & RELATED OBD[3]

OSI model	CAN UDS	OBD
Application Layer	ISO15765-3/ISO14229	ISO15031-5
Presentation Layer	N/A	N/A
Session Layer	N/A	N/A
Transport Layer	N/A	N/A
Network Layer	ISO 15765-2	ISO 15765-4
Data Link Layer	ISO 11898-1	ISO 15765-4
Physical Layer	ISO 11898-1	ISO 15765-4

As Shown in table 1, ISO 15765 support both CAN UDS and old OBD diagnostic method, OBD mean “On Board

Diagnostic", it was a legislated measure for road vehicle diagnostic. In this article we concern about CAN UDS only. The CAN UDS has no Presentation layer, Session layer and Transport layer, both data link layer and physical layer make use of ISO 11898 which is CAN bus international standards.

ISO 15765 part 1 is a general specification for whole CAN UDS, it introduces remain parts of CAN UDS and gives some important concept in CAN UDS such as architecture and related standards. Part1 shows the overview and relationship of different parts. ISO 15765 part 2 gives a general specification of UDS network layer, which was used to diagnose device across different network, such as from power train bus to implement bus. Both single frame (non-segment frame) and multiple frames (segment frame) are introduced. SF is used to report some immediate error code and if one frame is not sufficient for the message, it will be divided several different frame and send under the Flow Control Mechanism's control. To the residual error codes it needs to be report in multiple frames, as shown in figure 1.

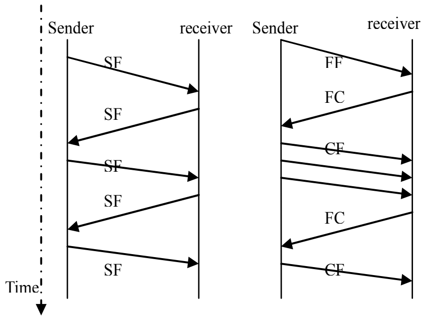

Figure 1. Single Frame and MultiFrame

ISO 15765- part 3 is a simplified ISO 14229, more detailed information is described more clearly in latter. It is a core part of CAN UDS, most application services used by diagnostic are produced in this part. As mentioned early, there are mainly 25 (in ISO 14229 25, ISO 15765 24) services of diagnostic, can be divided into diagnostic and communication management functional unit, data transmission functional unit, stored data transmission functional unit, I/O control functional unit and upload/download function unit. ISO 15765 part 4 describes the OBD diagnostic requirement and it is useless in CAN UDS.

B. Choosen Essential Parameters of Customizable Measure

As mentioned above, a customizable diagnostic measure is introduced and not only for road and non-road vehicle but also for automation application such as DeviceNet, CANOpen, etc. CAN based customizable diagnostic measure (CCD Measure) make use of XML to customizable information. The customizability is based on formal method[7][8]. Although fingerprinting[7] is an useful information, but in this article it wouldn't be concerned.

A protocol is a series of statutes to transfer data correctly and efficiently. Protocol means "A set of standardized procedures for transmitting or storing data, especially those used in regulating data transmission between computers or peripherals."[7] From the view of analysis and diagnostic, an application protocol can be described in four metrics, as shown in formula (1), a protocol can be defined by Format, Error message, Timing and Action. To perform diagnostic, extra information helpful for analysis is Statistic parameters and Other diagnostic information, as shown in formula (2), where F mean Format, T mean timing, S mean Statistics and OD mean Other Diagnostic parameters.

$$P = \{F, E, T, A\} \tag{1}$$

$$D = \{F, T, S, OD\} \tag{2}$$

Format parameters describe structure information of protocol, such as how much fields there are and how many bytes every fields occupied. Vary protocols may have same identifier but different format or same format but different identifier. To CAN bus (2.0B) based network, there are always 29 ID and 8 bytes data, but the explanation were very different from vary protocols.

An application protocol may have various application protocol data unit (A-PDU), but all of them may have same basic format named Root Format, and other kinds of PUD inherent from the Root Format PDU. The hierarchy diagram is shown as figure 2, the root of all format is named Root Format, which may include some important and basic coding rule, such as CAN ID's explanation, it describes an application protocol's basic structure. Level1 Format inherent from root format and can be treated as a "primitive" level, L2 format is service level. The hierarchy between different level of PDU format may achieved by XML.

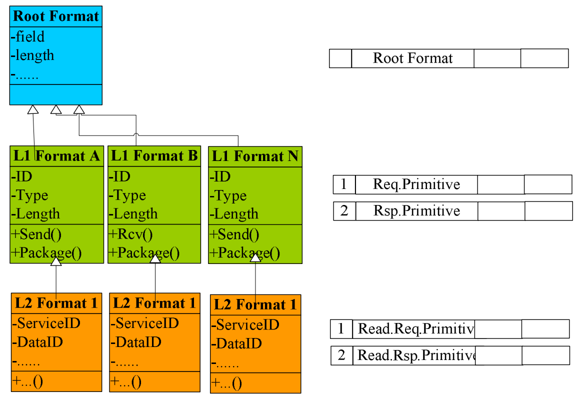

Figure 2. PDU Format Hierarchy

Timing parameters is a time line profile of communication,. When a protocol working, timing parameters describe all the outer activities between different communication peers, which services PDU to be sent, what time and which one response PDU should be sent are defined by timing parameters.

Statistics Parameters are important attributes to diagnostic and analysis of protocol, but not core attributes of protocol definition. Typical statistics parameters are bus load rate, error rate, certain application layer service occurs count, retry count, etc.

Other diagnostics parameters are group of diagnostics parameters which user interested or needed. Those parameters depend on the application protocol to be analyzed. For example, ISO bus has a "Parameter Group Number" (PGN), different

PGN respect some physical value, such as ground speed, wheel speed. Some PGN's occur ratio may be very important for analysis of ISO bus.

C. Customizable Diagnostic Measure Design

According to (1), and because F, E, T and A are a type of set also, there are the following formulas:

$$\begin{cases} F=\{f_1,f_2,\ldots,f_m\} \\ E=\{e_1,e_2,\ldots,e_n\} \\ T=\{t_1,t_2,\ldots,t_n\} \\ A=\{a_1,a_2,\ldots,a_n\} \end{cases} \quad (3)$$

To illustrate what are "F, E, T, A" look like exactly, a SAE J1939 basic profile is given following as an example. SAE J1939 is a supported protocol by this tool and basic PDU format of SAE J1939 is given as follow picture.

Priority :3bits	Dp: 1	Reserved:1	PDU Specification:8	PDU Format:8	Source Addr:8

Figure 3. Basic pdu format of SAE J1939

As figure.3 shown, a pdu format concerned field type, field name, field length, and so on. Filed name can be treated as variables, such as pri (priority), dp (data page), length can be handled as coefficients, such as 3, 1, etc. According mentioned above, figure3 can be translated an algebraic format as f_1, formula (4). Formula (4) e_1 is an "error" element of E formula (1), which means negative acknowledgement with error code "-1" and address "error_addr". Formula (4) t_1 means a request primitive can be responded by a response primitive.

$$\begin{cases} f_1 = 8*pri+1*dp+1*r+8*pf+8*ps+8*sa \\ e_1 = -1*ack*error\_addr \\ t_1 = 100 \\ a_1 = req+rsp(0) \end{cases} \quad (4)$$

This formula will be converted into RPN (Reverse Polish Notation) to deal with computer conveniently. The transform will be done by computer program, thus the xml input would look like formula (4), but latter will be changed into RPN format.

$$\begin{cases} f_1 = 8pri*1dp*1r*8pf*8ps*8sa*+++++ \\ e_1 = -1ack*error\_addr* \\ t_1 = 100 \\ a_1 = reqrsp0*+ \end{cases} \quad (5)$$

Formula (4) and (5) shows a little part of prime definition of protocol SAEJ1939. The f_1 is an algebraic form of figure3 PDU format.

Protocol system fault detection is often conducted by active testing [9] and action analysis. To diagnose the network and each node more clearly, three sets are made, they are normal set, abnormal set and error set. Normal set includes protocol information provided by formula (1), at last it will turn into RPN format like formula (5). Normal set can be predefined by user, it is easy to develop vary protocol's RPN definition according mentioned above. When RPN format protocol definition has been fulfilled, empty abnormal set and error set should be established meanwhile. When it is first run, all traffic on the net work should been captured and analyzed according to RPN protocol definition in normal set. If the traffic is consistent with normal set P_1,P_2, or P_i, it should be a "right " or "normal " action, otherwise, it is an abnormal or error action and the action will be put into abnormal set. An abnormal action will be treated as error action only when user made it. Both abnormal set and error set can be preserved for future. Normal, abnormal and error sets' relationship is shown in following picture.

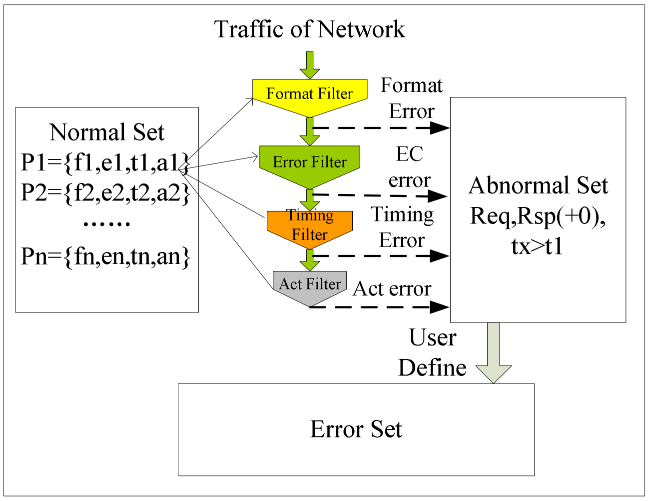

Figure 4. Normal , abnormal and error set

As figure.4 shown, traffic of network will be analyzed according to rules of normal set, compare with P_i (i=1…n) until match or finish, if f_i, e_i, t_i or a_i is not matched, compare with P_{i+1}, if three of four elements are matched but still not all matched with P_i, put it in abnormal set with P_i' (an abnormal P_i) otherwise put it as a new element. If user picks up an element of abnormal set and let it belong to error set, then it will be moved into error set.

Customizable characters are reflected in translate protocol definition to RPN formula approach, by this way any protocol can be defined clearly and easily.

D. Customizable diagnostic meature model

As mentioned above a protocol's analysis is defined by 4 metric essential parameters named F,T, S and OD. A customizable diagnostic measure model is given in this part. Formal Protocol Rule Interpreter (FPRI) is a core concept in CCD measure, it should take 4 metric parameters namely F, T, S and OD.

Customizability is achieved by the FPRI and some Formal Protocol Describe File (FPDF), according to protocol 4 metrics attributes, there are 4 FPDF configuration files. FPRI translate protocol definition to RPN format like formula (5). The four files and other needed files can describe a certain protocol as well as pre-programmed one. FPRI read and interpret the former files to parameters in four metrics, the interpreted parameters are sent to runtime general protocol analysis. The runtime general analysis handle unpackaged raw data stream and explain PDU to physical information. Explained PDU and corresponding physical information are sent to display model, by which list physical information of PDU, unpackaged PDU data, timing information, statistics information and diagnostic information, as shown in figure 5.

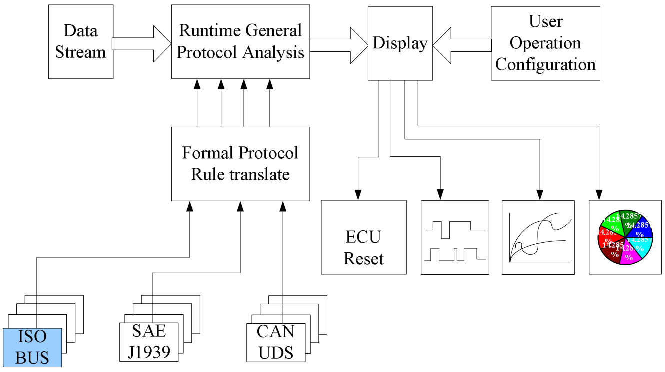

Figure 5. Customizable diagnostic measure mechanism flaw

Runtime general protocol analysis module is responsible for semantic retrive, which means data mapping to semantic. The physical and diagnostic information are created online according to runtime created semantic interpretive rules (according to configure file FPDF). User operation configuration module provides a configuration interface to user, by which operator may decide what kind of data should be displayed and how to do it.

III. The Design of Unified Diagnostic Platform

A customizable unified diagnostic platform consist of definitions, specifications, data structures, program modules and inter relationship between them.

A. The Architecture Design and Analysis

This platform can be divided into the following parts: CAN bus access device, basic software module, application software module. KVASER leaf light acts as CAN bus access device, cause of it is minimal in physical size and has sufficient supports for developer. Basic software is consisted of driver module, formal protocol rule interpreter, the application module include runtime protocol analysis module, display module and user configure module. As shown in figure 4, the platform is divided into several parts.

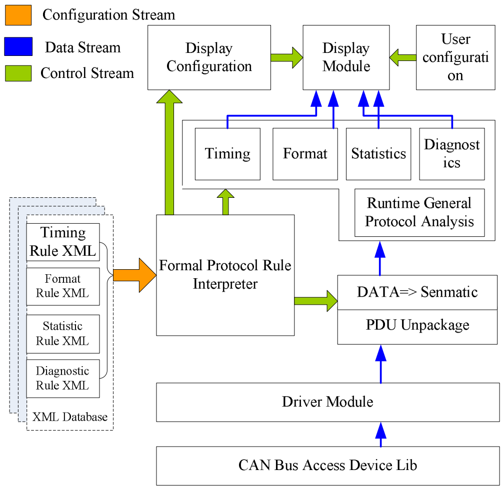

Figure 6. Unified Customizable Diagnostic platform's model structure

As figure 4 shown that blue lines means "data stream", data stream comes from CAN bus and process step by step in our platform and become into some analysis/diagnostic data finally. Salmon pink lines means "configuration stream", those configuration come from user defined FPDF described by XML, in which timing, format, statistics and diagnostics restrict are given. Meanwhile the green lines mean "control stream", the control information define related module's activities.

CAN bus access device lib and driver module provide an interface to access real CAN bus, by which data from CAN bus were captured in time. They are the glue between CAN bus access hardware and the upper application.

Formal protocol rule interpreter is respond to interpret FPDF XML to computer program, the source is formatted nature language or diagnostic formula, and the destination is computer program or corresponding parameters. Formal protocol rule interpreter take one input and produce three output streams.

XML data base including four kinds of FPDF, it provide rule staff to formal protocol rule interpreter.

B. Platform Software and Its Deployment

This software platform is developed by C++ builder and EVC, the CAN bus access tool is KVASAR leaf light. The software's interface is shown as Figure 7.

The platform software can decode and diagnose different CAN based protocol concurrently, as figure 7 shown there are three kinds of protocol named SAEJ1939, ISO Bus and UDS are decoded, analyzed and diagnosed. These three protocols have same root format, meanwhile there are some differences at format hierarchy level 1 and level 2 (figure2). The platform software has decoded J1939 TP.DT, UDS SF and UDS FF frame. The left top area gives a detail diagnostic of UDS, the left middle area decoded SAEJ1939-73's diagnostic information. Because of CAN based protocols have same root PDU format, the decoding and diagnostic program can be integrated together.

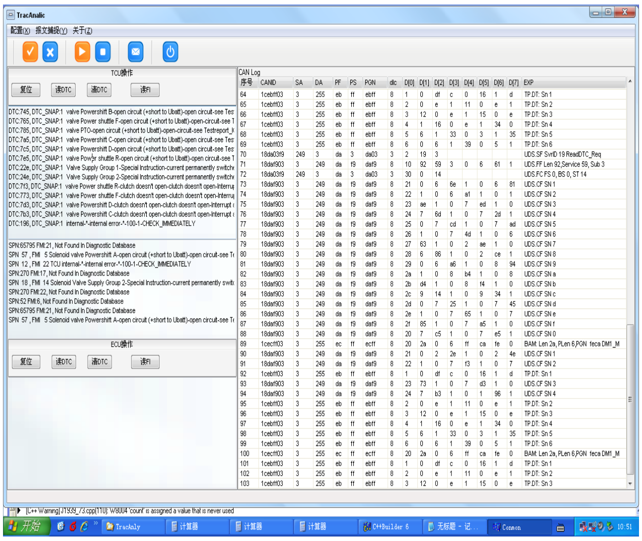

Figure 7. CAN based Customizable diagnostic Platform

The Platform software can be easily applied in Tractor to diagnostic, the application approach is shown as following. Both PC and Wince embedded devices can be make use of.

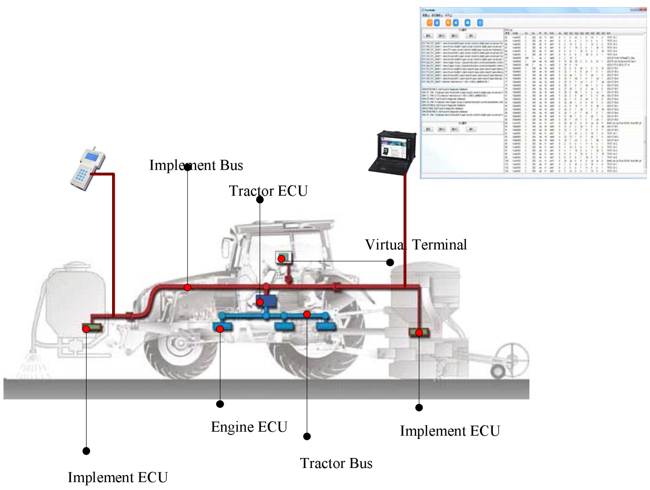

Figure 8. CAN based Customizable diagnostic Platform

The Platform software is applied in 200 horse-power wheeled tractors and 300 horsepower wheeled tractors of YTO Group Corporation, which was biggest tractor and argiculture machine manufacture in China.

IV. THE DESIGN OF UNIFIED DIAGNOSTIC PLATFORM

A customizable diagnostic of CAN bus based network analysis and diagnostic platform software is designed and realized. Customizable diagnostic parameters are given, furthermore, a customizable diagnostic measure based on protocol RPN definition is introduced.

This platform software can be defined easily and clearly by user, such as SAEJ1939 and ISO bus or other CAN bus based networks. The platform software not only decode or analysis every frame on network, but also spy every challenge-response communication action. And based on the traffic action statistics parameters, a network status can be defined and provide more detail information to user. This platform software was used at YTO Group Corporation.

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