

## **IoT solutions for Internal Combustion Engine Test Bench**

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### **Abstract**

In recent years, the concept of Internet of Things extends not only for devices used privately, but also to industrial facilities. Thus, the development of a distributed network infrastructure in the Industrial Control System led to the emergence of Industrial Internet of Things (IIoT), which allows for a significantly improve the possibilities of saving time and means of production for industrial enterprises due to the connection of all their processes at the executive level. Based on developed by authors concept, a schematic diagram of the "smart" test bench system used for the research of diesel engine is created and implemented. An original scheme for routing data in Internet has been developed. It gives the possibility to connect different customers for sending and receiving data using various protocols. As a data aggregator, the ThingSpeak™ cloud service is selected, and the integrated MATLAB® mathematical package is used as the analyzer.

**KEY WORDS:** *Internet of Things, Test Bench, Diesel Engine*

### **1. Introduction**

*Internet of Things* (IoT) is a set of physical devices, vehicles and other technical objects equipped with electronics, software, sensors, drives and network connection, that allow these objects to collect and exchange data independently. Moreover, each such object is identified uniquely through the built-in computing system and has ability to interact with other objects within the existing infrastructure of the worldwide *Internet* network [1,2]. According to experts, by the year 2020, the *Internet of Things* will include of about 50 billion devices [3].

Starting from 2017, the concept of *Internet of Things* extends not only for devices used privately, but also to industrial facilities. Thus, the development of a distributed network infrastructure in the *Industrial Control System* led to the emergence of *Industrial Internet of Things* (IIoT), which allows for a significantly improve the possibilities of saving time and means of production for industrial enterprises due to the connection of all their processes at the executive level.

Such technological processes include, among other things research and exploitation of internal combustion engines. Undoubtedly, the introduction of full or partial automation in the life cycle of these products will significantly improve their technical level, the quality and production speed as well as the comfort of exploitation.

It should also be noted that "communication" of things is done through "cloud" information technology using a special communication protocol MQTT (*Message Queue Telemetry Transport*), which is the standard for IoT because of its simplified service information, availability of publication / subscription model and bidirectional opportunities.

Based upon foregoing statements - **the relevance of the task**, defined in the present scientific study, is indisputable.

**The purpose of the work** is the implementation of *Industrial Internet of Things* in the life cycle of an internal combustion engine through creation of an "smart" research test bench.

### **2. The Concept of the Telemetry System and its Implementation**

The main idea of present research is to create a telemetry system used by remote users and capable for real-time visualization and analysis of engine's parameters obtained on the test bench. Thus the results of such an analysis can be used both for the adoption of subsequent scientific and engineering solutions and for the operational management of the test facility as well. Schematically, the concept is illustrated in Fig. 1 where there is one of the crucial elements is shown which is *IoT Broker - the Internet* source that allows to collect, store and provide on request all the telemetry data.

The realization of the proposed idea is based on the schematic diagram of data routing developed by the authors. Routing data schematic diagram takes into account the protocols of data transmission and shown in Fig. 2.

It should be noted that this scheme is based on the electronic fuel management system of the diesel engine, the composition and algorithm of which is open and described in detail in [3]. The electronic control unit of the engine has a microcontroller ATmega328, the parameters of which are presented in Table 1. The microcontroller ATmega2560 is selected as the basis for the electronic control unit of the "smart" test bench because it has acceptable parameters (see Table 1). The interaction of these controllers is realized by means of consecutive consistent transmission of data through their serial ports.

The data transmitted between the controllers are the parameters of the automatic fuel management system in the form of  $X$ ,  $H_p$ ,  $n$  - the current position of the engine control unit, the rack position of high pressure fuel delivery pump and the crankshaft rotation speed respectively. The rest of the operating parameters of the engine are received in the form

of signals from analog sensors directly to the input ports of the electronic control unit of the test stand. These are the magnitudes:  $M_c$  - loads on the engine;  $G_{fuel}$ ,  $G_{air}$  - fuel and air consumption;  $P_{air}$ ,  $T_{air}$  - pressure and air temperature at the inlet;  $T_{water}$ ,  $Toil$ ,  $T_{eg}$  - temperatures of a cooling liquid, oil and exhaust gases temperature. In our opinion, such a set of parameters is sufficient for creation a predicative statistical model of engine operation.

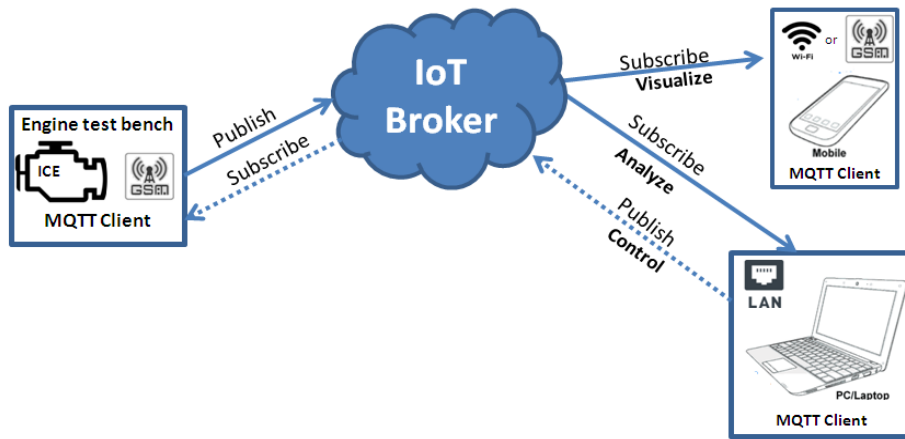


Fig. 1 The Concept of Smart Test Bench

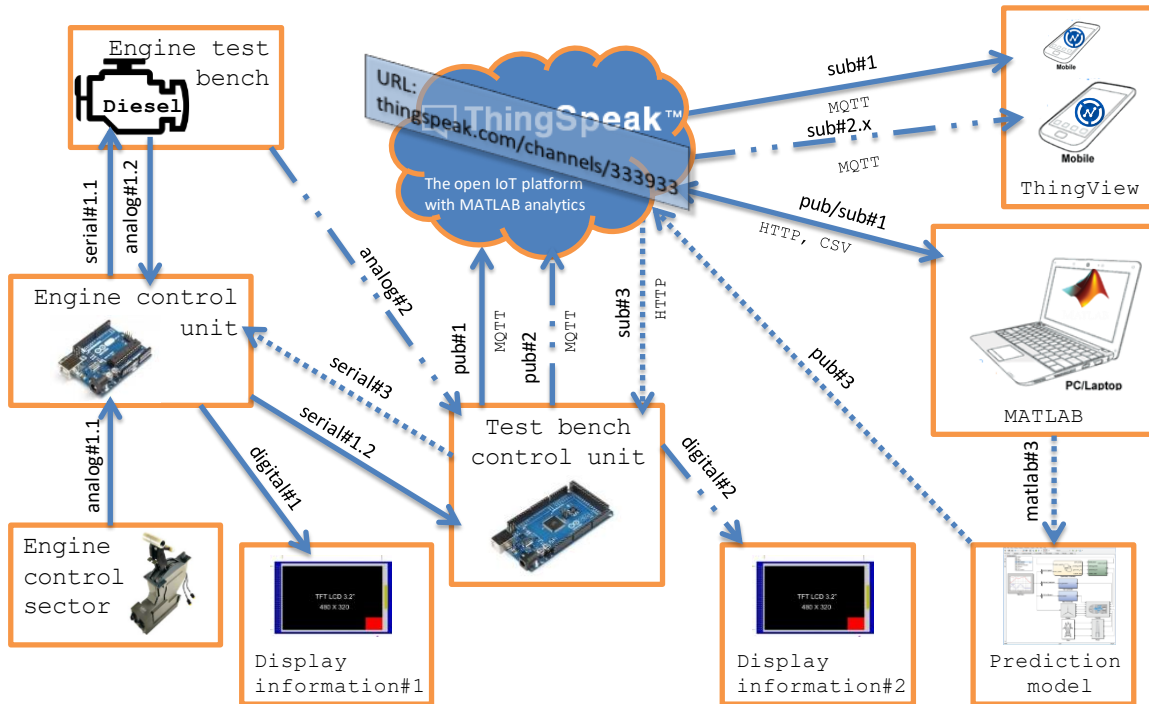


Fig. 2 Data routing through the Cloud

Table 1

Technical characteristics of microcontrollers

Microcontroller	ATmega328	ATmega2560
Clock frequency	16 MHz	
Flash memory	32 KB	256 KB
Boot Flash memory	0,5 KB	8 KB
RAM	2 KB	8 KB
EEPROM	1 KB	4 KB
Digital Inputs / Outputs	14	54
Analog inputs	6	16
DC current through the inputs / outputs	40 mA	
Input voltage of the ports	7-12 V	
Operating Supply Voltage	5 V	

The research engine is a single-cylinder diesel engine with a power output of up to 50 kW at a crankshaft rotation speed of up to 2500 rpm. Dimensions of the cylinder: bore 120 mm, stroke 140 mm. The installation is characterized by the following design features.

Injection of fuel into the cylinder is carried out by a high-pressure fuel supply with an individual fuel pump (*Unit Pump System, UPS*).

- Lubrication system - autonomous, with a dry crankcase.
- Cooling system - liquid, autonomous, with separate flows of coolant to the engine block and cylinder head.
- The engine is started by means of an electric load device included in the test setup.
- Lanchester type balancing mechanism.
- There is a gas channel in the cylinder head for installation pressure indicator.

The test bench is equipped with all the necessary instruments and sensors for measuring the parameters of the engine.

The Internet-client of the electronic control unit of the test bench is the GSM-900 mobile communication module, operating according to the 2G / GPRS standard. The module suits perfectly for a mobile telemetry system, and its transmitting power is sufficient to support packet data transfer using the MQTT protocol with a short time interval.

As a cloud aggregator and data storage medium, the ThingSpeak™ server is used as a remote resource. MATLAB® mathematical package integrated into the resource is utilized as data analyzer [4]. The choice of this particular resource is explained by the convenience of using all benefits from the environment of scientific and engineering mathematical calculations offered by MATLAB® software for data analysis, mathematical models creation and virtualization of research [5]. On the ThingSpeak™ server, this project has its own channel, which is publicly accessible through the URL address <https://thingspeak.com/channels/333933>.

For connecting and managing data on the ThingSpeak™ server, MATLAB® package includes special ThingSpeak Fetch and ThingSpeak Support Toolbox libraries [6]. The results of processing incoming data can be opened to the public access on the server or used for local needs, for example, to create a virtual predictive model. An example of local processing and visualization of data using MATLAB® package is shown in Fig. 3.

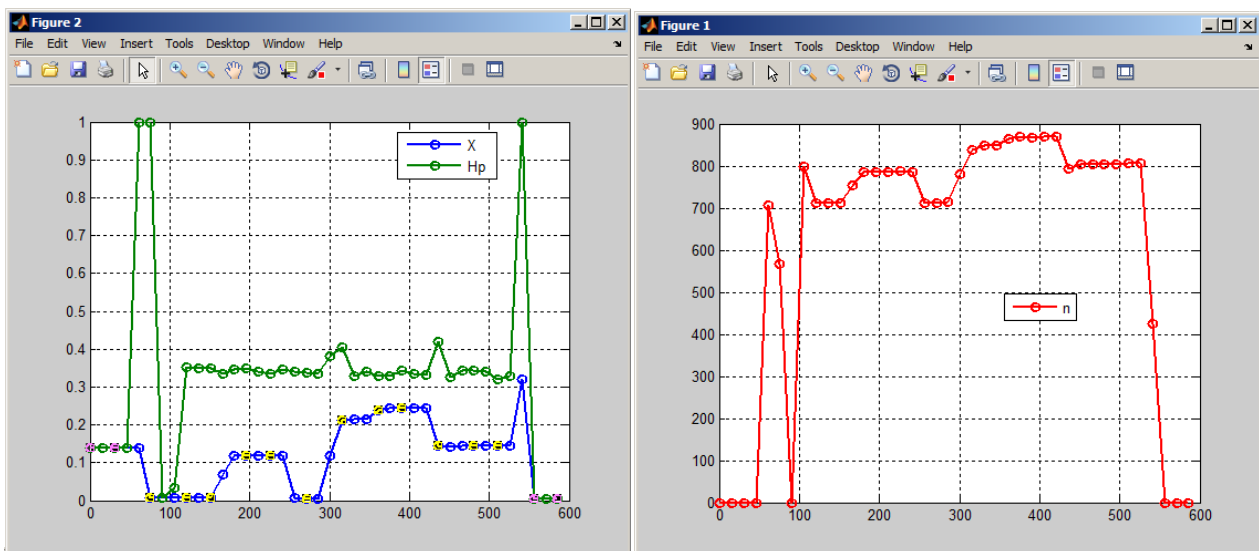


Fig. 3 An example of data processing and visualization in MATLAB

Android-based ThingView application could be used in the mobile Internet-devices for monitoring data incoming to ThingSpeak™ server.

The prospective tasks to be solved within the framework of this project are:

- reduction of the sampling interval for data packets transmission up to 1 s;
- creation of a predictive mathematical model of the experimental setup;
- creation of a feedback data stream for the organization of remote automatic (or manual) diesel control.

### 3. Conclusions

Based on developed in present study concept, a schematic diagram of the "smart" test bench system used for the research of diesel engine is created and implemented.

As a data aggregator, the ThingSpeak™ cloud service is selected, and the integrated MATLAB® mathematical package is used as the analyzer.

Practical testing of the developed system showed its reliability, ease implementation and confirmed the correctness of the developed concept.

An original scheme for routing data in *Internet* has been developed. It gives the possibility to connect different customers for sending and receiving data using various protocols.

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