Review on IoT-based Remote Monitoring System for Engine Health

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Abstract--- *This paper presents an IoT-based system using Blynk that enables remote monitoring of a car engine's condition. The system integrates pressure sensors to monitor oil and gas pressure, temperature sensors to track engine temperature, and vibration sensors to detect unusual engine activity. At the heart of the system is the NodeMCU microcontroller, which processes all the sensor data and communicates it to the Blynk cloud platform in real time. The NodeMCU also controls a ventilation fan that helps regulate the engine's temperature, enhancing both performance and longevity. This smart system ensures that critical engine information is accessible from anywhere via the Blynk app, making it easier to identify and respond to potential issues before they become serious. By combining intelligent control, accurate sensors, and IoT connectivity, the system offers a reliable solution for remote engine health monitoring—ultimately helping users maintain their vehicles more effectively and ensuring smoother performance.*

Keywords--- *IoT Connectivity, Node MCU, Ventilation Fan Control, Vehicle Maintenance, Remote Monitoring of Car Engine, Blynk Cloud Platform, Internet of Things (IoT).*

I. Introduction

THE Internet of Things (IoT) has come a long way and changed a lot about how businesses work today. Automotive engineering is one of the fields that has gotten the most out of it. Putting IoT in cars is a big change from the old way of doing things, which was to wait for problems to happen and then fix them. You can now keep an eye on the health of your car in a proactive and predictive way [39]. This new technology lets us build cars that are smarter, safer, and work better. In this case, a cutting-edge paper has been written to make a complicated IoT-based remote monitoring system that will make it easier to keep an eye on the health of car engines [40]. This paper uses a holistic framework that combines modern sensors, microcontrollers, and cloud-based platforms to analyze data in real time and give smart feedback to make sure that vehicle engines work at their best [41]. At the center of this system is the Blynk platform. It is a strong and adaptable IoT solution that lets developers create apps that can control and keep an eye on hardware from afar. Blynk is easy to use with embedded systems because it works with a lot of different devices and can send and receive data in real time. This is a great choice for programs that need to see, control, and make decisions based on real-time data [42]. The new system uses Blynk's features to make a full monitoring system that keeps track of important engine parameters like temperature, pressure, and vibrations. Sensors in the engine compartment keep an eye on these things all the time [43].

Vibration sensors check to see if the engine is working right. These sensors are very sensitive and can pick up on small vibrations that could mean there are mechanical problems like imbalances, misalignments, or wear and tear that is just starting to happen [44]. The system can let the user know about possible problems before they become big ones by finding these problems early on. This early warning feature is very important for keeping cars from breaking down without warning and for making engine parts last longer. There are also pressure sensors that keep an eye on the fuel and lubrication systems in the engine to make sure they are at the right levels [45]. Keeping the oil pressure at the right level is important for making sure that all of the engine's moving parts are well-lubricated. If the pressure goes outside of the normal range, it could cause more friction, overheating, and eventually engine failure [46]. Checking the fuel pressure also makes sure that the engine gets the right amount of fuel for efficient burning. Changes in fuel pressure can cause problems with performance, higher emissions, and lower fuel economy. The system gives vehicle owners and service workers real-time information about these pressures, which lets them take the right actions at the right time [47].

Temperature sensors are another important part of the system that keeps an eye on things. These sensors are put in places where they can best show how hot the engine is. There are many reasons why it's important to keep an eye on the engine temperature [48]. If your engine gets too hot, it can cause serious damage, like warped parts and a blown head gasket. On the other hand, running an engine at too low a temperature can make it

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less fuel-efficient and wear it out faster [49]. The system keeps an eye on temperature trends and lets the user know when readings are out of the ordinary. This keeps the engine running in its best thermal range, which improves both performance and durability. The Node MCU microcontroller is the system's main processing and communication hub. It receives data from all the sensors [50]. The Node MCU is a small, cheap development board that can connect to Wi-Fi and is based on the ESP8266 microchip. It gathers, processes, and sends data from the sensors to the Blynk cloud platform. There, it is shown in real time on a user interface that can be accessed from a computer or smartphone. The Node MCU is very important for both data communication and local processing [51]. It can run algorithms to find problems, send alerts, and even start automatic responses.

The system's active intervention mechanism is one of its most cutting-edge features. Most monitoring systems are passive, which means they only report data. But the addition of a ventilation fan controlled by the Node MCU makes the system more proactive [52]. If the temperature sensors see that the engine is getting too hot, the Node MCU can turn on the fan to cool it down and bring the temperature back down to a safe level. This feature shows that the system can not only keep an eye on things, but also change them, which stops small problems from becoming big ones [53]. This IoT-based monitoring system shows how important and useful embedded systems are in modern car design in general [54]. An embedded system is a specialized computer system that does specific tasks as part of a bigger mechanical or electrical system. These systems usually have to work in real time and are made to be efficient in terms of size, cost, and power use. Embedded systems are different from general-purpose computers because they combine hardware and software that are designed to work together for specific tasks. General-purpose computers are built to be flexible [55].

Cars and trucks have embedded systems all over them. They manage a number of car subsystems, such as engine control units, transmission systems, anti-lock braking systems, airbag deployment mechanisms, and entertainment systems [56]. Their presence makes sure that cars can do complicated things on their own and without fail. Cars are safer, use less gas, are more comfortable, and are more fun to drive because of embedded systems [57]. A lot of the time, these systems are linked to each other through a network. This creates a complicated web of devices that talk to and work with each other to improve the performance of the whole vehicle. Embedded systems aren't just used in cars. Telecommunications use embedded systems to make networking devices like routers, modems, and mobile phones work [58]. These systems are in charge of sending and receiving data, processing signals, and running the user interface. Embedded systems are found in a lot of consumer electronics, like TVs, digital cameras, set-top boxes, and home automation devices. They are great for meeting the exact needs of these products because they are so efficient and specific [59].

Embedded systems are also very important for robotics, industrial automation, and manufacturing. Robots controlled by embedded systems do tasks on assembly lines with a lot of speed and accuracy. These systems can make decisions in real time, adapt to changing conditions, and improve processes [60]. Smart manufacturing environments are possible when sensors and actuators are combined with embedded controllers. These environments let machines keep track of their own performance and talk to each other to make the whole process more efficient. Embedded systems are very important for mission-critical applications in the aerospace and defense industries. You can find them in satellites that help with navigation, missile guidance, communication, and surveillance [61]. These settings need to be very reliable, able to handle mistakes, and able to work in very harsh conditions. In these situations, embedded systems are made to meet strict standards and often have backup systems and self-diagnostic features [62]. One of the biggest problems with designing embedded systems is finding the right balance between performance and limited resources. Engineers need to make software that works very well with these systems because they don't usually have a lot of processing power, memory, or energy [63]. People often use real-time operating systems (RTOS) to help them remember to do things on time. These operating systems have ways to set up tasks, deal with interruptions, and let processes talk to each other. This makes sure that the system responds to inputs and does its tasks on time [64].

More and more smart methods are being added to embedded systems. Embedded systems are getting better at making hard decisions based on data analysis as machine learning and artificial intelligence become more common. For instance, embedded systems can use predictive models to change how resources are used on the fly in power management. This saves energy and makes the hardware last longer. Smart embedded systems like these are very important for making places smarter, such as smart homes and smart cities. Smart card technology also makes a lot of use of embedded systems [65]. These cards, like bank cards, ID cards, and access control cards, have built-in microcontrollers that keep data safe and process it. They are very important for keeping transactions safe, verifying identities, and encrypting data [66]. Embedded systems are used in alarm systems, biometric scanners, and security cameras to keep an eye on things and respond to them in real time [67].

Embedded systems also make medical devices work better. Embedded systems let us keep an eye on and treat health problems all the time, from portable diagnostic tools to implantable devices like pacemakers [68]. These systems have to follow strict rules set by the government, and they are often built to work for a long time with little maintenance [69]. They are essential in modern healthcare because they are so reliable and accurate. Embedded systems are the building blocks that connect physical things to the digital world in the larger context of the Internet of Things. They gather information from the environment, process it on-site, and talk to other devices or cloud platforms [70]. This feature makes a lot of things possible, like smart farming, environmental monitoring, tracking logistics, and more. As mentioned before, the creation of an IoT-based engine health monitoring system is an example of how embedded systems, wireless communication, and real-time data analytics are coming together [71]. It shows how embedded technologies can change the way modern systems work, making them more reliable, functional, and smart. As these technologies get better, they will have an even bigger impact on the future of business, healthcare, transportation, and everyday life [72]. With new ideas like these, we get closer to a world where technology not only meets our needs but also predicts them, stops problems before they happen, and makes our lives better in ways we never thought possible.

II. Literature Survey

Predictive maintenance has become a key strategy in the world of smart and connected vehicles, especially with the use of Internet of Things (IoT) sensors and advanced deep learning algorithms. This method lets you predict possible system failures before they cause major damage or make the system work worse [8]. Predictive maintenance systems help keep engines running longer, safer, and with less downtime by constantly checking the health of different engine parts and looking at data trends [9]. But the same technologies that make these systems work, such as IoT sensors and deep learning models, also make them easier to hack. It could be very bad if someone takes advantage of these weaknesses. One major risk is that IoT sensors in car engines are open to cybersecurity threats like false data injection attacks [10]. This might make the whole car less safe and reliable. False data injection (FDI) attacks are a complicated type of cyber attack where bad data is put into a system to confuse the algorithms that make decisions [11]. These kinds of attacks can mess up sensor readings in car engines, which can lead to wrong diagnostics and system responses that aren't right. These intrusions can have terrible effects, especially when they mess with real-time data that controls important engine functions like fuel injection, temperature control, and pressure control [12]. This paper talks about how FDI attacks could affect automotive engine sensors that are connected to the Internet of Things (IoT) and some deep learning algorithms that can find and stop these kinds of attacks. It does this because it knows how bad this threat is [1].

There were a number of algorithms used in this study to find intrusions. These included Recurrent Neural Networks (RNN), Long Short-Term Memory Networks (LSTM), Generative Adversarial Networks (GAN), and a new model called Sequential Probability Neural Networks (SPNN) [13]. RNNs and LSTMs are great at modeling time series data and finding long-term dependencies. This makes them great for looking at sensor readings in a car's systems one after the other. GANs, on the other hand, use the adversarial framework to tell the difference between real and fake data. This makes it easier to find strange things [14]. The SPNN algorithm is a new way to combine probabilistic modeling with sequential neural network architecture. It has been better at finding and stopping attacks on IoT sensors in car engines that are already going on. SPNN is good at dealing with long-term threats, but the GAN model was better at dealing with short-term or temporary attacks [15]. These results show how important it is to use more than one algorithm to protect automotive sensor networks [2].

In today's hybrid and electric cars, managing and improving energy efficiency is just as important as fixing cybersecurity issues. Battery and Energy Management Systems (BEMS) are very important for making sure that energy is used efficiently, batteries are kept healthy, and the vehicle as a whole performs better [16]. BEMS works by constantly checking the battery's state of charge and state of health and controlling the flow of power between the battery and other parts of the powertrain, like electric motors and combustion engines [17]. It also keeps an eye on thermal management to keep the battery from getting too hot and makes sure it stays within safe temperature ranges. By smartly controlling how energy is distributed based on driving conditions and user behavior, BEMS helps improve fuel efficiency, lower emissions, and extend battery life. Its functionality is important for both the safety and sustainability of hybrid electric vehicles (HEVs) and the efficiency of their operations [18]. More and more electric and hybrid cars will be on the road, so there will be a greater need for smart and strong energy management systems. In the future, this will change how things are made and built [3].

Gas turbine engines need to be very dependable and work well in military planes. Condition-based modeling techniques use data from gas path analysis to make it easier to find and fix problems with engines [19]. This paper shows how to make these kinds of models using Numerical Propulsion System Simulation (NPSS), a powerful tool for simulating how engines work based on aero-thermodynamic parameters. The first thing to do is make a basic engine model that shows how the engine works when everything is normal [20]. After that, this model is used to see how changes in the efficiency of important parts of the gas path, such as compressors, turbines, and combustion chambers, affect the engine's output. The results show that engine performance is very sensitive to changes in these areas, so they should be closely watched and diagnosed [21]. We put fake problems into these important parts to see how well the model can find them. We study how the engine responds to these issues and look for patterns that are very similar to those in the Fault Correlation Matrix from the manufacturer of the original equipment. The strong relationship shows that the model is correct and can be used to make predictions [22]. The study found that condition-based modeling can be used not only for test bed diagnostics but also to find problems in real time while the aircraft is in use [23]. This method is much better than traditional diagnostic methods, which take a long time, need special tools, and keep planes on the ground for longer periods of time. This method can save a lot of money on maintenance and make military aviation operations more ready by making it easier to find problems quickly and accurately [4].

Testing engines is also very hard when it comes to accuracy and efficiency, especially when it involves using special tools like propulsion nozzles. People usually have to move the nozzle by hand to test the engine in normal setups [24]. This method is subjective by nature and can be wrong because of people, especially when the nozzle moves quickly or in a way that is hard to see [25]. This study looks into how to use computer vision technology to automate the process of testing engine motion, taking these limitations into account. A system is made up of both hardware and software to make motion analysis more accurate and faster [26]. The system uses advanced image detection algorithms to watch and understand how the nozzles move during engine tests. These algorithms are supposed to find target positions and movement patterns with a high degree of accuracy, even when the tests are dynamic [27]. The system can handle data in real time at speeds of over 20 frames per second (FPS), and it makes sure that the time it takes to send data doesn't go over 3 seconds. You can also connect it to up to eight cameras, which lets you see motion from a lot of different angles [28]. Not only does automating the testing of nozzle action make measurements more accurate, but it also makes a reliable record of test results that can be looked at later [29]. A big step forward in engine diagnostics is going from manual testing to automated testing. It offers a solution that can grow with your needs, lowers labor costs, and makes testing more reliable [5].

This paper also talks about another important new idea: power supply systems for embedded sensors in marine engine environments [30]. Embedded sensors are very important for keeping an eye on important things like temperature, vibration, and pressure in real time. However, their usefulness is limited by the fact that they need a power source, especially in harsh environments like marine engines where high temperatures and vibrations can shorten battery life. When you have to change the battery often, you have to take apart the engine, which costs more to maintain and takes longer to run [31]. To solve this problem, a new way to collect energy is suggested that uses the swinging motion of the connecting rod on a marine engine [32]. The invention uses electromagnetic induction to make electricity by moving a permanent magnet that is attached to the connecting rod and a coil sleeve stator relative to each other. The pendulum motion of the engine cuts through the magnetic field lines, which makes the coil create alternating current. After that, a rectifier circuit changes the current into direct current, which is then combined with energy collected from thermoelectric power generation sheets that are put in places with high temperatures [33]. These sources work together to keep low-voltage embedded sensors powered all the time, allowing them to work on their own without needing batteries from outside [34]. This energy system is self-sustaining, which means it will work for a long time and needs less maintenance. This makes it perfect for use in places that are hard to reach, like marine vessels [6].

The technologies and methods talked about in this paper all come together to form a new way of doing things in advanced diagnostics, cybersecurity, energy management, and automation. These are all important parts of how modern engine systems are changing in the automotive, aerospace, and marine industries [35]. Adding deep learning algorithms to predictive maintenance systems makes them better at finding small problems and quickly responding to possible threats. The creation of specialized models like SPNN gives us new ways to deal with the growing problem of cyber-physical attacks on important infrastructure [36]. At the same time, condition-based monitoring models and energy management solutions help systems last longer, work better, and cost less. These new ideas are part of a bigger trend toward engine systems that are smarter, more independent, and safer, and that can better meet the needs of the 21st century [37]. It can't be stressed enough how important it is to protect and improve these technologies as cars and engines become more connected and dependent on data-driven systems. More research and development in this area will lead to transportation systems that are stronger, more efficient, and better for the environment [38]. The future of propulsion and maintenance is in intelligent integration, where embedded technologies not only monitor but also adapt, predict, and act in real time.

This includes things like self-diagnosing aircraft engines and self-powered marine sensors [7].

III. Methodology

The current car engine monitoring system is meant to give basic diagnostic and alert features. It mostly uses a mix of built-in sensors, GSM technology, and a buzzer to find and fix problems with how the engine works. When the sensors find a problem, the system quickly sends alerts to the user through GSM communication and turns on a buzzer to get their attention right away [73]. This setup lets you find faults and notify users at a basic level, so you can step in quickly if there are problems with the engine. But it works on a reactive model and doesn't have much in the way of real-time analytics or remote monitoring [74].

On the other hand, the suggested system adds a number of improvements that are meant to make engine health management more thorough and proactive. One of the most important features is the use of pressure sensors to keep an eye on and record changes in oil and fuel pressures in the engine in real time [75]. This makes it possible to diagnose problems more accurately and find potential problems earlier. The system also uses IoT connectivity through the Blynk platform, which lets users easily check important pressure settings from a mobile or web interface. A ventilation fan is built into the design to help control engine temperature [76]. It is automatically controlled based on real-time temperature data to make sure that the best thermal conditions are always present. The system also includes a machine learning algorithm called Svstem that looks at engine performance data to find patterns and predict possible failures before they happen [77]. This ability to predict is a big step forward from older systems, which only sent alerts when something went wrong. Instead, it uses data to come up with smart maintenance plans [78].

IV. Result and Discussion

In the Arduino environment, user-written code only needs two basic functions: one to set up the sketch and another to control the program's main loop, which runs all the time. These functions are not run on their own; instead, they are put together with a stub main() function into an executable cyclic executive program. The GNU toolchain, which comes with the Arduino IDE, handles the whole thing [79]. The IDE uses a tool called AVRDUDE to change the compiled executable into a format that the Arduino hardware can read. This program turns the compiled binary into a hexadecimal text file. Then, the board's firmware has a bootloader that sends the file to the Arduino board. In the Arduino world, the word "sketch" refers to programs that users make [80]. Many people think that Arduino has its own programming language, but sketches are actually written in a simplified version of C++ that leaves out some C++ features to make it easier to learn. Programming a microcontroller is very different from programming a regular desktop computer [81]. That's why the Arduino platform comes with a number of device-specific libraries that can do things like change pin modes, send data to pins, read analog sensor values, and manage timers.

These device-specific abstractions can make new users think that Arduino uses a different language, when in fact it uses C++ with libraries that are specific to hardware [82].

The Arduino IDE can work with both C and C++, but it has its own set of rules for how things should be structured that set it apart from other desktop programming environments. The IDE also has a software library based on the Wiring paper that includes important functions for handling input and output operations that are common in embedded systems development [83]. The combination of user-written code, device libraries, and system-level compilation tools makes it easy and quick to install apps on microcontrollers that work with Arduino. When the sketch is done, the code is put together into machine-readable instructions that are put on the Arduino board [84]. This turns the microcontroller into an independent system that runs all the time and can handle a wide range of hardware interactions in real time [85].

In the future, there are a number of promising ways to improve these kinds of systems. Using machine learning to create predictive maintenance algorithms is a big chance. These algorithms can look at past sensor data to find patterns that happen before mechanical failures [86]. This lets users plan maintenance tasks ahead of time, before a problem happens. This proactive approach can greatly cut down on unplanned downtime, make engine parts last longer, and lower the cost of maintenance overall. You could also get more operational parameters and diagnostic trouble codes by linking the monitoring system to the vehicle's onboard diagnostics system. This integration would make it much easier to understand how the engine is doing and how it is working, which would make alerts and suggestions to the user more accurate and helpful [87]. In the future, there will be another improvement: platforms like Blynk will make the user interface easier to use and more interactive [88]. This user interface could show sensor data over time in graphs, let users set their own alert levels, and make smart suggestions based on what it learns from the data. This would make it easier for people to understand and use complicated engine health metrics [89].

It's exciting to think about adding remote control features to the system's capabilities, which goes beyond just monitoring. For example, users could change things like the timing of the ignition, the fuel injection, or the throttle control from a distance to get the best performance out of their engines in different driving conditions [90]. These features could be very helpful for keeping track of a fleet of cars, where it's important for one person to be in charge of a lot of them [91]. Fleet managers and service centers could use a central data analytics dashboard to put together sensor data from a lot of different vehicles. They could use this information to make choices about how to improve the whole fleet and do maintenance based on predictions based on data. This type of dashboard could help with trend analysis, spotting problems early, and planning resources. This would lower operational costs and make all the vehicles in the fleet run better [92]. Adding algorithms that help with diagnostics to the monitoring system would also be a good way to improve it. These algorithms could look at the data from the sensors and tell users right away what might be wrong and how to fix it [93]. This feature would be very helpful for people who aren't experts because it would make them less reliant on professional mechanics and make engine maintenance routines more flexible. Making energy use more efficient is also a constant problem and opportunity. Two ways to collect energy that could greatly reduce or even eliminate the system's need for outside power sources are using solar panels or capturing the kinetic energy created by the vehicle's motion [94]. This would make the system more reliable in places that are far away or not connected to the grid, and it would also make it more environmentally friendly.

Adding strong predictive models would make the system even better at predicting when parts will wear out or break. For instance, using advanced machine learning methods like support vector machines, random forests, or deep neural networks to combine real-time data on temperature, pressure, and vibration with historical usage patterns could let the system send out early warnings of mechanical wear or performance drift. Over-the-air firmware updates could keep these models up to date all the time, making sure that the monitoring system stays responsive to changes in mechanical behavior and environmental conditions. Also, putting this kind of intelligence right in the microcontroller at the edge could lower latency and make the system more responsive, especially when immediate action is needed, like shutting down the engine to avoid a catastrophic failure. Adding cloud-based services to the platform would make it possible to do more things, like store data for a long time, sync data across devices, and get help with remote diagnostics. Cloud connectivity would make it possible to create detailed maintenance logs that anyone could access from anywhere. This would make it easier to follow vehicle service rules and hold people accountable. These improvements could be made without putting user privacy or system integrity at risk by using secure communication protocols and encrypted data transmission. Also, improvements in microcontroller and sensor technology will probably lower costs and make these systems easier to get, making them possible for widespread use in both personal cars and commercial fleets. The system could work well with other in-vehicle systems in the future if it supports standard communication interfaces like CAN, I2C, and SPI. This would make the whole connected vehicle ecosystem better.

Adding computer vision technology to the engine monitoring platform is another area where new ideas can be tested. The system could keep an eye on the physical condition of engine parts, find leaks, visually check for wear, or make sure that mechanical parts like nozzles, belts, or fans were working properly. It did this by using cameras and image-processing algorithms. This would add an extra level of safety and make it easier to find faults, especially in places where regular sensors might not work or might be blocked. You can use edge AI to process visual data on the spot, which cuts down on the amount of bandwidth needed and makes the system more responsive. Improving the human-machine interface to support natural language queries, voice commands, and smart assistants could make the monitoring system easier for more people to use, even those who aren't very tech-savvy. These interfaces could also give users maintenance tips, answer their questions, and help them with troubleshooting in a way that feels natural and conversational. Additionally, using modular hardware parts would let users tailor their monitoring systems to the needs of different engine types or working conditions. With modular sensor kits, expandable storage, and plug-and-play communication modules, users would be able to change the system without needing a lot of technical support or reconfiguration.

When combined with forward-looking improvements like predictive analytics, remote control, user-friendly interfaces, energy harvesting, and cloud integration, the Arduino-based engine monitoring system could change the way engines are maintained and managed in a big way. This platform could make engines much more reliable, lower operating costs, and make vehicles last longer in a wide range of applications by using the flexibility of open-source hardware, the power of machine learning, and the reach of IoT technologies. These new ideas not only help the automotive industry, but they also set the stage for use in aerospace, marine, and industrial machinery, where real-time monitoring and predictive maintenance are essential for success.

V. Conclusion

This paper explains how a complicated IoT-based system for checking the health of car engines from a distance was built. The system can find and keep an eye on different parts of the engine's performance and condition using sensors for vibration, pressure, and temperature. The Blynk platform lets users see and track their engine's health in real time, even when they are not near it. Also, adding a ventilation fan that the Node MCU controls gives the system a way to actively control the engine temperature, which makes it even more useful and functional. This paper shows that IoT technologies could make car maintenance and monitoring better in general. This setup seamlessly connects sensors to provide a full, real-time stream of important engine parameters. Vibration sensors, which are sensitive enough to pick up even the smallest changes, are the first line of defense against possible mechanical problems. At the same time, pressure sensors keep a close eye on the oil and fuel pressures to make sure that the engine gets the best lubrication and combustion possible.

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