Adaptive Highway Networks: An IoT Solution for Improving Road Safety at Turnovers and U-Turns

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Abstract: *Highway construction is a crucial component of any region's infrastructure, and it is carried out in several different ways nowadays. Adaptive Highways Network (AHN) uses sensors and microprocessors for automatic design. Innovative highway design employs roadside controls and intelligent vehicles for traffic management and control. The Automated Highway System enhances highway safety, operational efficiency, and other vehicle and user characteristics. This innovation has enhanced the architecture of highways and reduced vehicle emissions. AHS, or Smart Road, is a projected intelligent transportation system technology for driverless automobiles on specific roadways. It is commonly employed to alleviate traffic congestion since it reduces following distances and permits more vehicles on the road. Together, the car and the roadway strive to avoid barriers, boost traffic flow, and decrease congestion. The AHS concept integrates vehicle intelligence, intelligent highway infrastructure, and vehicle-to-infrastructure communication technology.*

Keywords: Adaptive Highways Network (AHN), Internet of Things

I. INTRODUCTION

The Adaptive Highways(AHN) Network redefines the link between vehicles and roadway infrastructure. AHS refers to lanes on a limited-access highway where vehicles with specific equipment operate automatically. AHS employs vehicle and road control technologies to transfer driving responsibilities to the vehicle. The Adaptive Highways Network is a transportation infrastructure geared toward the future. AHS technology creates a new interaction between transportation modes and road networks. Autonomous vehicles employ an automatic control system. Advanced computing, microelectronics, sensors, and civil engineering are required to design an autonomous highway system. New intelligence-based methods are being implemented to connect highways and automobiles. This scientific device is operated by mechanical and radio controls. The purpose of automated highway systems is to boost the capacity of fully managed traffic networks. The AHN will contribute to innovative solutions that increase mobility in a controlled manner by applying low-pollution, high-safety, and high-efficiency technologies to a separate infrastructure or on current roads. Such transit systems will be incorporated into future transportation scenarios. Future transportation needs will be supplied by innovative transport solutions. In our opinion, new transport system concepts will increase the efficiency of road travel in urban areas while also contributing to the goal of achieving zero accidents and eradicating nuisances.

Utilizing sensor, computer, and communications systems in vehicles and along roadways, full automation would be achieved. In locations where road extension is physically impossible, politically untenable, or prohibitively expensive, fully autonomous driving could permit closer vehicle spacing and higher speeds, improving traffic capacity. Automated controls may increase road safety by reducing driver error, the leading cause of collisions. Further potential benefits include improved air quality (due to more efficient traffic patterns), increased fuel efficiency, and spin-off technologies. Monitoring external infrastructure with the aid of communication, sensor, and obstacle-detection technology. Together, the car and roadway strive to avoid barriers, boost traffic flow, and decrease congestion. The AHN concept integrates vehicle intelligence, intelligent highway infrastructure, and vehicle-to-infrastructure communication technology. The Adaptive Highways Network has been essential in the management of transportation networks in industrialised cities. AHN will be advanced by lane departure warning. first system to regulate the lateral movement of a vehicle. Adaptive cruise control will add lanemaintaining after lane departure warning. The future of AHN is contingent upon roadside-to-vehicle and vehicle-to-vehicle links.

According to the community, AHN will advance technologically by means of little steps. Full automation will not be a sudden change, but rather the logical conclusion of previous efforts and implementations. Each technological step will support itself. Vehicle and infrastructural evolutions that are "synchronised". Before presenting the AHN programme and automatic vehicle control technologies, we will briefly explain this development. Safety and user acceptance were issues when cruise control was introduced, but it is now widely used. The infrastructure for modern cruise control and communications will soon include obstacle and headway warnings as well as AVI.

Combining cellular connectivity and high-performance computers with vehicle innovations is essential for AHS. The roadway system should be divided into "cells" with local radio receivers or beacons that are connected via fiber-optic cables. A vehicle's transceiver will provide user services. The early implementations of this technology are AVI and ETC (ETC)[1]. Next for AHS in vehicles is obstacle and forward collision warning. Two years ago, VORAD systems were installed in numerous commercial vehicles. In warning systems, sensor module capabilities are significant. Large vehicles may not be distinguished from small animals by simple systems. Automatic headway control is an application of a headway warning system. Many automakers design adaptive cruise control systems. The first vehicle with adaptive cruise control is scheduled in 1997. This enables drivers to maintain speed and distance travelled. Many users may choose to set the desired headway, even though "creepers" will be cut off by more aggressive drivers (Chunters). In addition, problems such as sensor types, curve handling, merging cars, changing lanes, and steering and brake integration must be addressed. ATM, ATIS, and APTS necessitate increasingly sophisticated vehicle location capabilities. The popularity of vehicle-to-roadside communications will increase. MAYDAY, fleet tracking, and AVL applications will utilise sophisticated transceivers and radio-location beacons. and AVI allow vehicle location processing in real time. A tiny proportion of AVI/AVI.-equipped vehicles can be used as "probes" by traffic management centres[2].

1.1 Advanced Traffic Management Systems (ATMS)

Advanced Traffic Management Systems (ATMS) are concerned with a road network region (e.g., congregated sections of the freeway network or parts of the urban or rural network). The importance of traffic performance on the remaining road networks is diminished for ATMS. For the area in question, ATMS aims for maximum traffic performance at the system level, which entails serving as many vehicles as feasible while minimising total travel time. In this technique, ATMs strive for a system-optimal configuration. To achieve system optimal, ATMs need information regarding actual system performance on the entire road network. Traffic management methods are required for ATMs to dynamically adjust or distribute provided traffic over available infrastructure capacity. Information about traffic (and infrastructure) should be accessible in real-time (every 1 to 5 minutes, for example) and include aggregated traffic figures. Decisions and measures are implemented by traffic managers at the traffic centre, who supplement external data collection with training and knowledge.

Due to the fact that the administrators of ATMS applications are the road authorities, who are also responsible for the road infrastructure, an ATMS monitoring system is based on fixed traffic detectors installed in, above, or along the road infrastructure. This category of detector relies on infrastructure[3]. Due to the network-wide orientation of ATMS, a monitoring system employing infrastructure-based, fixed traffic detectors (e.g., inductive loops) has vast detector spacing (usually 5 to 10 kilometres). Shorter distances between detectors would increase the expense of network-wide monitoring.

1.2 Advanced Traffic Control Systems (ATCS)

ATCS is a "supplement" to the ATMS. ATCS focuses on local chokepoints such as bridges, tunnels, and on- and off-ramps. ATCS optimises local site traffic throughput. Serving as many automobiles as quickly as possible reduces overall time lost. ATCS targets local optimization. ATCS instruments are stringent standard operations that can be fully automated without human intervention. ATCS is not a legitimate information system according to the definition of information systems (component people are not involved). By adjusting settings, the ATMS is able to modify the ATCS's objectives. Because ATCS computations and actions must be performed in real-time, computer model complexity and calculation speed restrict the system's applicability in large areas. ATCS data must be precise, relevant to specific vehicles, and real-time (e.g., in intervals of several seconds to one minute)[4].

1.3 Advanced Traveller Information Systems (ATIS)

Road users may only be concerned with the optimal path from their origin to their destination when road authorities strive to optimise their transportation system (user optimum). This may be represented as a minimal travel time (or a minimal generalised time) for the entirety of their journey.

To support and optimise individual users, ATIS gives information about complete routes from origin to destination, delays on the typical route, travel time on alternative routes, and alternative transport alternatives at the time of passage[5]. This implies that certain parts of varied networks (urban, rural, and state) are useful during a specific trip, such as information about delays on routes at the time they would be used (requiring short-term projections). ATIS traffic data may be obtained every 5 to 15 minutes (incidents should be reported more swiftly). These features conflict with the information requirements of ATMS applications, which require real-time network-wide data. Due to the regional and network-based nature of ATIS data, an ATIS monitoring system cannot always rely on stationary traffic detectors. Due to the dense urban road infrastructure, it would be impossible to install fixed traffic detectors on an entire metropolitan road network[6]. Due to the dissimilar objectives of ATMS and ATIS, an ATIS monitoring system should be autonomous from an ATMS monitoring system and should not utilise infrastructure-based traffic detectors. Probe cars with non-infrastructure band detectors can be used for ATIS. Nonanal automobiles fitted with GPS and a communication device transfer traffic data to a traffic centre.

II. RELATED WORK

Researchers and vehicle developers have studied about adaptive highways extensively. These studies show adaptive highway benefits.

The concept and operation of the Nuzzolo Advanced Traveler Advisory Tool (ATAT) It should assist consumers in traversing multimodal networks by recommending their preferred routes. Using the path utility estimation of the Random Utility Theory, such pathways are identified. The first section describes TVPTA implementation inside a city. Analyses conducted by the authors following the selection of a sample of students travelling in the metropolitan region reveal the advantages of giving personalised information and the inadequacies of supplying travel advice using aggregate models[7]. Experimental evidence reveals that model initialization and updating require additional study. Even though Stated Preferences interviews on two-alternative scenarios with a minimum of ten observations allow us to estimate initial model parameters for a satisfactory individual travel recommendation, the updating process is slow and too many observations are required to obtain statistically significant results.

BAUBLYS The transport system is analysed as a complex system with all of its defining indicators, enabling the application of systematic and operational analysis in national transport systems and component studies[8]. classifying complicated transportation networks as objects of management. This classification must be founded on technological and theoretical indicators, as well as the delineation of system management challenges resulting from temporal coordination with the hierarchical structure of complex systems. Transport management and national transport system development based on the theory of complex systems management may reveal a number of qualitatively novel concepts that increase transport efficiency and realise its potential for economic and technological advancement. From long-term projections to operational management, the management of complex transportation systems seeks to plan and sustainably grow. Chien Describe the problem of tracking a density profile. Using a macroscopic traffic model similar to that in, they construct a controller that dictates a desired speed at each roadway segment so that its density conforms to a specified profile[9]. Their simulation simulates human driving. It is possible to design automated vehicle control regulations so that they function similarly to human-driven cars, but this is not the only approach. The established control law inverts the dynamics of traffic flow, necessitating the controllability of traffic flow. Florez, Jose Describe the multimodal transportation system of a large firm. In this study, we combine LP with automated planning to produce effective solutions. Due to the non-linear optimization function and limitations, direct application of traditional LP techniques is difficult in this field[9].

Hisdrick Describes concerns with autonomous vehicle control. Particular attention is paid to control system design and lateral and longitudinal "platoon" control[10]. Khattak Create a simulation to evaluate how users respond to diverse information sources (ATIS with full compliance, radio reports, and observation). Under undersaturated and oversaturated conditions, the average delay for all travellers is reduced with the full compliance ATIS model[11]. Bruglier Promoting public transportation, Intelligent Transport Systems, and transit accessibility for all populations may help reduce urban traffic congestion and air pollution. The author designs and develops a real-time mobility information system to manage unanticipated public transportation events, delays, and service disruptions[12]. Massive volumes of data are processed, stored, analysed, logically associated, and graphically displayed by the P.K. GIS. GIS-based ATIS is a helpful tool for storing and graphically displaying information. Using advanced GIS functions, a user can conceptualise a problem and allow the appropriate software to aid with route selection and trip planning.
According to Qu and Chen[13], multimodal transport is an MDP (MCDM). They propose a hybrid MCDM resulting from the combination of a Feed-forward AINN and an FAHP. A network of terminals and transit modes constitutes the case study (road, ship and train). The model can accommodate several cost functions and constraints, however it has only six nodes, whereas our maps have thousands. Zhang Wenjie Conventional ITS can only recognise a vehicle in a stationary location, and their wires raise the cost of building and maintenance. It is anticipated that the usage of wireless sensor networks (WSN) in ITSs will overcome the aforementioned obstacles due to their low power consumption, wireless distribution, and lack of cable restrictions. This paper proposes a transportation information system based on WSNs. The designers create hardware and software WSN module prototypes. This author presents ITS with WSN.

III. COMPONENTS REQUIRED

The hardware components and nodes are chosen to make the proposed system for their suitability in the highway systems to reduce the accidents and power consumption.

3.1 Devices

Integration of the prototype comprises seven hardware components. Along with an Arduino UNO, Ultrasonic sensors, LED streetlights, power converters, photoresistors, Lithium-ion batteries, and solar panels were used.

A. Arduino UNO

Arduino UNO is an open-source microcontroller board based on the microchip ATMega328P microcontroller developed by Arduino released in 2010. Board consists of PWM pins, ADC converter and I/O pins that are used to interface with the external environment. Board equips with 14 digital I/O pins, 6 analog I/O pins and programmable with Arduino IDE via a type B USB cable.

B. Series 2-X-Bee with 2 milliwatts of power over a wire antenna

With improved power output and data protocol, the Series 2 module allows you to create a complex mesh network based on the X-Bee ZB ZigBee mesh firmware. These modules can be used for simple communication between microcontrollers, computers, systems etc through a serial port.

C. X-Bee Navigator USB

A second X-Bee series 2 module is connected to the computer and utilized for communication with the module with help of an X-bee navigator USB. The board can be configured with the X-CTU software that is made available by Digi International Inc., and incoming data can be read by using this program.

D. Sensors

Ultrasonic sensors and light-dependent resistors were the sorts of sensors that are used to monitor the highways to avoid accidents and save electricity.

1. Ultrasonic sensors are electronic devices that are used to calculate the target's distance by emission of ultrasonic sound waves and convert those waves into electrical signals to detect the objects. Ultrasonic sensors

are used to detect the approaching vehicles to turn on the streetlights and also indicate dangers at the U-turn by signals in order to regulate accidents.

2. Light-dependent resistors are used to detect the sunlight by the light rays falling on it by the change in resistance. It was used to save power by sunlight falling on it. It also check the time before deciding the sunlight and sunset by the timer built in it. When there is no sunlight, Led will turn on based on the ultrasonic sensor readings.

E. Power Converter

A power converter is a converter that changes the electric energy from one form into the desired form optimized for the specific load. A power converter is used to solar panel current into the current required for the sensor node. A lithium polymer ion battery could be charged using this module. The power converter turned off when the voltage dropped below 3V and waits till for the battery to recharge while it was in standby mode.

F. Solar panel

The solar panel comprises of several individual solar cells to produce electricity. It was powered by a PV Logic Polycrystalline solar panel (STP010P). Despite its small size, the solar panel produced 22V at a maximum of 5W.

G. Lithium-Ion Polymer (LiPo)

Lithium-Ion Polymer batteries are used to store the electricity from solar panel to power the sensor nodes. The electrolyte within the battery is gelled, it does not require a stiff case the electrode in order too function properly. These allows lithium ion batteries works to be moulded into virtually any that may be required by application.

Table 1: Parameters of Sensor Nodes

Parameter	Value
Power Source	6600mAh
Arduino Energy Usage	72mAh
X-bee Current Usage	38mAh
Ultrasonic sensor current usage	32mAh
LDR current usage	0.9mAh
Sample Frequency	0.5Hz
Transmission Interval	2s

III. PROPOSED MODEL

Reducing accidents on highways is a critical challenge that requires innovative solutions. One of the main causes of accidents on highways is the lack of clear indicators for drivers when it comes to turnovers and U-turns. The dividers of the roads are often covered with trees, making it difficult for drivers to see other vehicles approaching from the opposite direction. To tackle this issue, we propose a simple IoT model that will alert drivers of incoming traffic. The model will involve placing sensors on both sides of the road, which will communicate with each other wirelessly[12, 13]. When a vehicle approaches a turnover or a U-turn, the sensors on one side of the road will detect its presence and send a signal to the sensors on the other side of the road. This will trigger a warning signal on the road surface, indicating to the driver that there is oncoming traffic. The IoT model we propose does not require complex algorithms or expensive hardware, making it a cost-effective solution that can be deployed on a large scale. The sensors can be powered by batteries, and the wireless communication can be established using low-power protocols such as Zigbee or LoRaWAN.

The proposed circuit for the IoT model to reduce accidents on highways consists of various components that work together to provide real-time alerts to drivers. The circuit includes sensors such as ultrasonic sensors and LDR sensors, as well as a solar panel for power generation. The ultrasonic sensors are placed on both sides of the road and are used to detect the movement of vehicles. These sensors send signals to the microcontroller, which processes the information and sends it to the wireless module for communication with the other side of the road. When a vehicle approaches a turnover or a U-turn, the sensors on one side of the road will detect its presence and send a signal to the sensors on the other side of the road. This will trigger a warning signal on the road surface, indicating to the driver that there is

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oncoming traffic. The LDR sensors are used to detect the level of ambient light and are placed near the solar panel. Based on the light level, the microcontroller turns on the LED lights on the road surface, indicating to drivers that there is a U-turn or a turnover ahead. The LED lights are only turned on during nighttime or low light conditions. The solar panel is used to power the entire system, eliminating the need for external power sources. The solar panel is connected to the battery, which stores the energy generated by the panel. The microcontroller and the sensors are powered by the battery, and the wireless module communicates wirelessly with the sensors on the other side of the road.

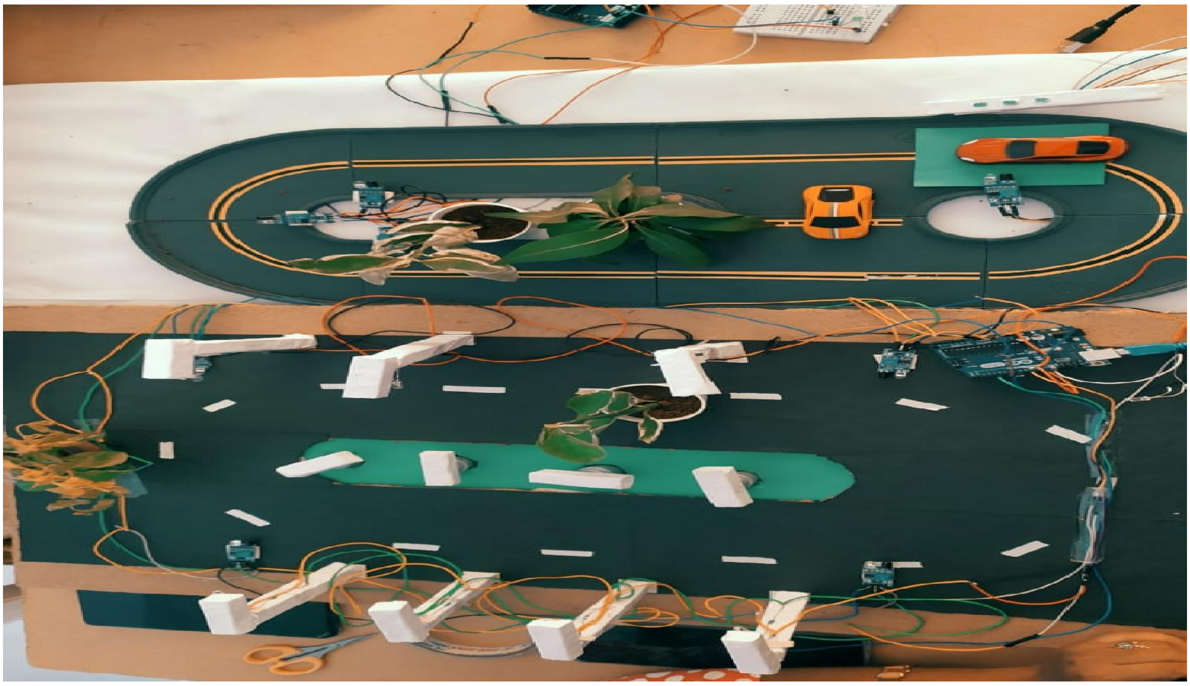

Figure 1: Deployed model

The wireless module is used to transmit data between the sensors on both sides of the road. The module uses low-power protocols such as Zigbee or LoRaWAN, which ensure efficient communication between the sensors. The circuit is designed to be cost-effective and easy to deploy. The sensors and the wireless module can be powered by batteries, and the solar panel provides renewable energy to the system. The LED lights on the road surface are low-power, and the system does not require complex algorithms, making it easy to manufacture and maintain.

IV. CONCLUSION

In conclusion, the proposed IoT model for reducing accidents at turnovers and U-turns on highways is a promising solution that addresses a significant safety concern. The system employs simple yet effective components such as ultrasonic sensors, LDR sensors, LED lights, and a solar panel for power generation, all of which work in tandem to detect and alert drivers of potential dangers on the road.

The use of renewable energy sources in the form of solar panels is an eco-friendly solution that reduces the carbon footprint of the system. The wireless communication between the sensors, along with the low-power protocols employed, ensures efficient and reliable data transmission. The proposed system's simplicity and cost-effectiveness make it a viable solution for deployment on highways across the country, particularly in areas where dividers are covered with trees, making it difficult for drivers to see oncoming traffic. In essence, the proposed model provides an innovative approach to improving road safety on highways, and if implemented on a large scale, it has the potential to save countless lives and prevent serious injuries resulting from accidents at turnovers and U-turns.

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