RESEARCH PAPER

Comprehensive Techniques for Intelligent Transportation Systems: Issues and Solutions using Wireless Sensor Networks

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***Abstract*—** Communication, cutting-edge electronic and computer technologies, control, and detection are all related to the intelligent transportation system (ITS). WSN is a collection of minuscule, interconnected sensor nodes that can do the real-time computation, wireless communication, and sophisticated sensing. Through the transmission of real-time information, it improves safety, effectiveness, and traffic situation. The real-time gathering of transportation data and communication between targeted nodes play a big part in all ITS applications. It is exceedingly difficult and expensive to deploy a wired sensor for data collection and communication from a wide area. Wireless sensor deployment offers an appealing platform for data gathering and dependable communication in ITS due to the cheap maintenance costs. In this paper, the fundamental ideas and practical information needed to create an objective and routing protocol for WSNs are described. The most important factors that may be used to classify ITS systems according to their primary function are road safety, traffic flow management, and reliable communication. Nonetheless, network reliability and traffic flow control are partially connected. For instance, a collision between two or more vehicles might result in a traffic jam. This incident's details provide a safety warning for incoming drivers to be informed of the situation. Information that may be used for a range of purposes and is transmitted over an ITS network with a solid infrastructure. The network distribution in ITS using different WSN methodologies is also addressed, which can help different researchers understand different challenges in developing the WSN-based ITS.

***Index Terms*—**Intelligent Transportation System, Wireless Sensor Network and Vehicular Ad-hoc Network, Clustering, Routing Protocol.

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I. INTRODUCTION

The uses of cutting-edge advances, including information & communication technologies (ICT), data sensing with navigation systems, integrates under the aegis of intelligent transport systems (ITS). The principle point of utilising such innovations in transport is to mitigate existing concerns including traffic flow control, traffic congestion, air and clamour contamination by redefining information gathering for tending to the vehicle-related concerns. ITS applies propelled advances of gadgets, sensing, detecting and communicating the desired information in the transportation framework. It also possesses in mind the end goal to enhance efficiency, services and security through transmitting real-time data. Deployment of a wired sensor for the data gathering and correspondence from the substantial geographic range is extraordinarily troublesome and exorbitant [1]. WSN is a blend of little-interconnected sensor hubs with detecting, figuring and remote correspondence abilities. Likewise, organizations of sensors are arbitrarily scattered and low support cost. These elements of WSN give an alluring stage to data gathering and correspondence in ITS. In ITS utilizing WSN, there are two varieties of sensor hubs utilized: fixed sensor node (FS) and the mobile sensor node (MS). FS nodes are randomly scattered in the vast region, and MS nodes are put in vehicles. Today, traffic congestion is the most vital social issue, and various researcher works for reducing congestion.

In the last decades surely, ITS attracted the automotive industries, researchers and governments. The different projects have been conducted by governments and research institutes from the whole of the world. ITS integrate innovative technologies of electronics, sensing & detecting multiple objects and real-time communications, in all kinds of the transportation system. This integration improves efficiency, safety, services and traffic situation by the exchange of real-time information [6]. There are four integrated components of ITS. These components include Intelligent Infrastructure, Smart Vehicles, Transportation User and Information Services, as shown in Figure-1.

- **Intelligent Infrastructure:** Intelligent transport system's backbone is infrastructure. Intelligent infrastructure utilizes the advances in servers, road traffic signal, message sign-board and efficient road-side unit. The key is to use the information exchange with a vehicle to infrastructure that relevant to help obtain full potential of both old and new infrastructures.
- **Smart Vehicles:** As the traffic density is increasing, the information exchange between vehicles to vehicles becomes more difficult. Therefore, smarter vehicles utilize advanced sensors, GPS and Data communication technology.
- **Information Services:** One of the essential objectives of ITS is to have enhanced services, efficiency and security. It also provided movement circumstances data information to the transportation user in real-time. Information Services includes mobile internet, Emergency notification real-time traffic information and traffic jam/accident notification.

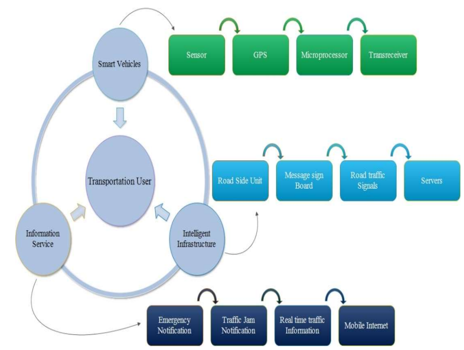

Fig.1: The components included in ITS.

One of the essential objectives of the intelligent transport system is to enhance safety by decreasing danger. There is a vehicular telematics approach for creating to accomplish safety and profitability in transportation framework [2]. Recently the ADAS (Advanced Driver Assistance Systems) has been intended to enrich road safety and increase driver comfort. In any case, the impact of ADAS on individual and gathering level needs to examine[3]. A decade ago, because of the popularities of the Internet of Things (IoT), a few research endeavours had examined rising IoT application situations. The accessibility of gadgets, smart mobile phone and a remote sensor, organized empower physical gadgets like RFID and similar technology provides a platform to universal coordination [4][5]. Based on the advances in smart vehicles and intelligent infrastructure, ITS delivers real-time traffic situation of the geographical region to the transportation user and also provides accident information to the concerned authority. It is also utilized in electronic toll collection, speed enforcement and vehicles control technologies. Based on function, the intelligent transportation system is classified into five systems as follows[7]:

- **ATMS (Advanced Traffic Management System):** ATMS involves application such as speed governance, accident management, e-toll collection, traffic light control and traffic jam on roadways. The primary function is to detect traffic status and also transmits information to the control centre via a communication network. The traffic control centre compute the information and apply the different traffic control strategies.
- **ATIS (Advanced Traveller Information System):** ATIS includes changeable message signs, GPS, internet, advisory, television, fax, telephone, information Kiosk and mobile. This system provides real-time information which makes road user more informative and helps in choosing the best travel route and transportation modes.
- **AVCSS (Advanced Vehicle Control and Safety):** AVCSS uses advanced

communication technologies in vehicles and intelligent infrastructure. It provides information to the drivers for their vehicle control, which improve safety. It also includes driving assistance, an anti-collision system, longitudinal control and long-run plans for automatic driving.

- **APTS (Advanced Public Transportation System):** It applies all the technologies of ATMS, ATIS and AVCSS in public transportation system. This helps to improve QoS and increase efficiency, which leads to the number of people who choose public transportation. The system involves vehicle governance, GPS, and E-toll collection.
- **CVO (Commercial Vehicle Operation):** It applies all the technologies of ITS in commercial vehicles such as ambulance, buses, commercial trucks and commercial cabs. This improves transparency among service provider and end-user. The system includes automatic e-toll collection, e-payments and vehicle monitoring.

The paper is divided into sections, and Section 2 provides a more in-depth analysis of the wireless sensor network. The WSN based ITS approaches that was taken into consideration is discussed in Section 3. The comparative study are discussed in the Section 4. In conclusion, the paper is summed up in Section 5.

II. Wireless Sensor Network (WSN)

The new innovative technologies in wireless communications and multi-functional sensor nodes make WSN is the ultimate cost-effective in data gathering from a broad geographical region. One of the leading advantages of WSN is low power and low cost. WSN tiny nodes are capable of observing environmental and physical conditions such as temperature, light, pressure and humidity. Based on observed information commands are generated to operate devices such as motors, switches that control different environmental and physical conditions. The tiny nodes are mostly distributed in the sensor field [8] as shown in Fig.3.

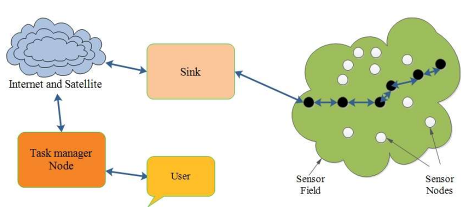

Fig.3: Sensor nodes distributed in a sensor field of WSN.

Every tiny sensor nodes have abilities to collect data from the dispersed area and send the data back towards the sink. The sink forwards these data via internet or satellite to the task manager. The data is analysed, and the information send to the user by the task manager. The WSN has an advantage and capability to collaborate a large number of nodes for gathering the valid information, which is not possible from a single sensing node. In WSN deployed thousands of sensor nodes in a broad geographical region where these sensors detect the environmental conditions. The collected data computed and communicated to desire node in a well-organized way. WSN applications in different fields such as rescue operation, environmental, health, building surveillance, military application etc. [9]. Application of WSN is shown in Fig-4.

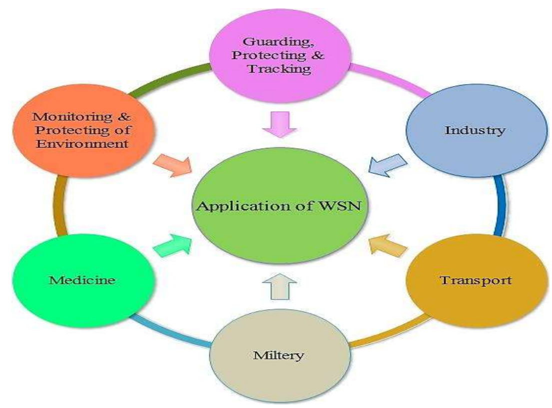

Fig.4: The application of WSN.

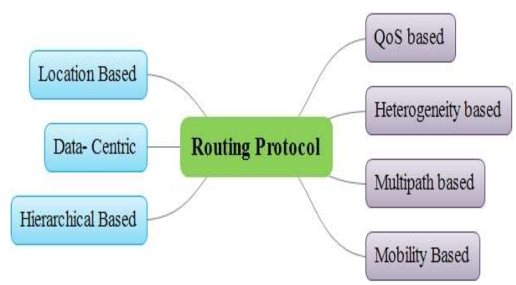

Fig.5: The categories of the routing protocol used in WSN.

A. The location-based routing protocol:

The location of sensor nodes is helpful for calculating the routing path among two particular nodes. This results in a saving in energy consumption considerably [10]. C.F Wang et al., 2014 proposed an Energy-Aware Sink Relocation (EASR) algorithm, which implements the energy-aware routing with the maximum capacity path for the mobile sink in WSNs. The sensor node, which is located close to the sink consumes more battery power than others, that is why their battery energy drain out quickly, and this leads to decrease the network lifetime. Based on maximum capacity and maximum energy proposed mechanism relocate the sink, this can increase the lifetime of networks.

B. Data-centric protocol:

The originating node sends data to the nearest sink, the routing node implement data aggregation techniques on sending data from the different sensor node. After aggregation of data, informative data is sent in the direction of the sink node. This approach can reduce some redundancy from data transmission, which causes energy saving for WSNs. [11] W. Liu & Y. Wu, 2013 proposed a well-organized power-efficient genetic-based and uneven distribution clustering routing algorithm (EHUGC-OAPR) showed the experimental result. This routing approach effectively balances the energy consumption, which improves the data delivery ratio of the network.

C. Hierarchical based protocol:

Routing decision depends upon the clustering approach, in which each cluster head is responsible for data transmission in their coordinating area of all the sensors. Researcher investigating different aspect in WSN such as routing protocol, energy-efficient protocols, coverage problem, network establishments etc. [12] S. K. Singh, 2010 review the energy-efficient hierarchical cluster-based protocol, which summarized the routing overhead is reducing using clustering the network that makes network lifetime is more prolong and also faster communication can be possible in WSN. [13] R. R. Rout et al., 2012 proposed network coding based probabilistic routing (NCPR) scheme. In this scheme, the authors reduce the broadcast storm problem, which is beneficial for clustered WSN. [14] B. K. Maddali, 2015 proposed CNSMR protocol compromises the different energy nodes. This algorithm uses the CNs (core node) and SNs (sensor node). The CNs has higher energy and computational power than SNs. In particular geographic region, the CH (cluster head) responsible for controlling the tasks like monitoring the energy state, topology and routing of the network. The primary function of CN is updating the path between CNs and nearby SNs. For participating in multicast, the SN energy should higher than a threshold value; else, it is an invalid member. If the distance between CNs and CHs are very high, then extra CNs are positioned in WSNs. The SNs are participating in multicast routing then only we can find a reduction in energy consumption significantly.

D. Mobility based protocol:

The mobility of the sink node is very challenging. The routing protocol makes sure data delivery within the network from a source node to mobile sinks. [15] L. Shen et al., 2011 proposed a mobility-based clustering protocol, which can improve the adaptability of the mobile node in WSN. On the basis of residual energy and mobility, sensor node originates itself either a cluster head or non-cluster head in the network. [16] A. W. Khan et al., 2014 proposed (VGDRA) on virtual grid-based and dynamic routing scheme which define a set of rule for reducing the cost of communication. On the basis of this rule, the sensor node re-adjust their routing path by sensing the existing position of the mobile sink. [17] H. Lin et al., 2015 proposed a fan-shaped clustering protocol which helps to divide this vast scale network into many small fan-shaped clusters. This division is governed by the well-defined rules. The experimental results show the optimization in cost of intra-communication, also reduces the frequency of re-clustering. [18] M. Abo-Zahhad et al., 2015 proposed a sink mobility-based routing protocol, which divides the extensive scale network into an efficient clustering network. This approach leads to address the energy-hole problem in WSNs.

E. Multipath based protocol:

The sensor node finds the different shortest path towards the sink node and distributes their load between these different paths. This approach provides higher reliability of the sensor networks. [19] A. Thakkar and K. Kotecha, 2014 proposed Energy delay index for trade-off (EDIT) algorithm, which shows the extensive simulation between energy and information delay.

F. Heterogeneity-based protocol:

The data communication between two types of sensor nodes, one type of sensor node which has battery power and other has no power constraints. [20] D. Kumar, 2014 proposed S-EECP and M-EECP clustering protocol and show the experimental result for competent selection of cluster head. These protocols save energy in node communication, which increases network lifetime.

G. QoS based protocol:

These protocols are responsible for the delay, fault tolerance and reliability of WSNs. [21] Z. Teng, 2010 reviewed the different type of real-time MAC protocols based on different attributes like timeless, energy-efficient and adaptability of WSN. [22] C. Cheng et al., 2011 proposed a data collection algorithm which provides efficient routing path in a network based on crucial time delay. The awareness of the acceptable value of time delay and communication distance, it selects a path in such a way that the collection time is significantly short. [23] S. H. Jokhio et al., 2012 proposed the SCADD protocol, which can detect as well as defence against the capture node. [24] A. E. Zonouz et al. analysis the evolution of application and communication reliability approach. In this approach, the identification of the K-coverage sets within the network is made first. It collects the information by continuous monitoring of delivering data between the sink and sensor nodes within K-coverage set. Secondly, in this phase analysis, the observed data and then estimates the communication reliability index. The reliability index enhance a quality services in the network by diminishing a network coverage problem. [25] Iliev 2015 suggested TERP routing protocol, which uses two-phase. In one phase with the help of distributed trust model, it detect and isolate the defective and isolated node within network. In second phase, this algorithm makes load balancing among trusted nodes. This approach shows the improvement in throughout, lifetime and energy consumption in network, as compared with existing research work. [26] C.B.N. Lakshmi et al. 2016, proposed Ant colony optimization based routing approach, which improves the network lifetime with an optimal routing path as shown in the experimental result. The most recognized fields of study, WSN routing protocol has been explored in the last few years.

III. WSN BASED INTELLIGENT TRANSPORTATION SYSTEM

Intelligent transportation systems (ITS) is the fast-growing field by the uses of advanced in electronic technologies. The advances in communication and information processing technologies are used for enhancing transportation efficiency and safety. A vital role in all intelligent transport application is transportation information collection and communication [27][28][29]. Deployment of a wired sensor for the information collection and communication from the large geographic area is challenging and costly [30].

In ITS, network distribution is the most useful application in the transportation system. Many researchers believe that Agent-based approach is one of the most impotent technologies which can be used for network distribution in traffic and transportation system [31]. An Agent system has two types of agent's: stationary and mobile agent. This algorithm provides mechanisms for agent communication, supervision and directory maintenance. It also supports the relocation and implementation of mobile agents. This technology is used in ITS, such as roadway system, transportation system, railway systems. Today, traffic congestion is the most important social issue for humans. The various researcher works for reducing the congestion. Traffic congestion can be reduced by :

a) Improve the existing infrastructure,
b) Sharing the resources,
c) Notification or variable message sign on the roadside
d) Reliable communication.

In fact, vehicular traffic continually increases the whole world, especially the urban area. The existing infrastructure of traffic surveillance, traffic flow maintenance and traffic control are not capable in terms of cost-effective, better performance and easy maintenance. WSN effortlessly deploy in traffic light control application. WSN provides a quick update of traffic information which analysis and apply strategies for traffic flow control as compared to existing infrastructure. WSN based infrastructure reduces congestion and average waiting time [32][33][6]. The state of global traffic congestion level in the entire network during specific time intervals is evaluating and based on evolution pattern clustering, and prediction is performed, which can improve the traffic flow [34]. Many researchers believe that congestion can be reduced by sharing the vehicle such as car-pooling concept [35] or car-sharing concept [36]. Some researcher believes that by deploy of notification or variable signboard on the road-side, which provides the incident information prior to congestion area makes help to reduce the congestion [37][38][29]. During the congestion area communication overhead on network increases, which causes information is lost. The information loss or packet loss can be reduced by decentralized congestion control method [39][40]. One of the primary goals of ITS is to improve safety by reducing risk. The researcher explore various vehicular telematics approach for developing to achieve safety and productivity in the transportation system [2].

Table I: Routing Protocol For WSNs

Routing Protocol	**References**	**Classification**	**Energy-efficient method**	**Data aggregation**	**scalability**	**Query-based**	**QoS**
EASR	[55]	Flat	Sink relocation	No	limited	Yes	No
EHGUC-OAPR	[56]	Hierarchical	The energy-based Cluster head	Yes	Good	No	No
NCPR	[57]	Hierarchical	Reduce broadcast storm in a cluster network	Yes	Good	No	Yes
CNSMR	[58]	Hierarchical	Heterogeneou	No	Good	No	No

			s node				
MBR	[59]	Hierarchical	Cluster head selection parameter is mobility and residual energy	Yes	Good	No	No
SCADD	[60]	Flat	N/A	Yes	limited	Yes	Yes
ACR	[61]	Flat	N/A	Yes	limited	No	Yes
IMHT-LEACH and DMHT-LEACH	[62]	Hierarchical	Minimize data transmission distance	Yes	limited	No	No
P-SEP	[63]	Hierarchical	Elect Cluster head based on average energy and probability	Yes	Good	No	No
EARP-	[64]	Hierarchical	Genetic Algorithm	No	Limited	No	No
GA			for data sharing				
MAHEE	[65]	Hierarchical	Cluster head based on higher Energy	Yes	limited	No	No

The major contextual factors that can use for predicting the risk are human context, environmental context, location context and dynamic vehicle state [41]. Based on these factors determine the vehicle behaviour and provide the proper feedback for the vehicle operator and making the safest distance by speed adjustment [42]. Although more and more studies have reported on prediction algorithm for vehicles behaviour, location, lane changes and tracking [41][43][44][45] and based on prediction making an effective braking system so the risk of accident can be reduced [46]. Nowadays, advanced driver assistance systems (ADAS), which provides driver comfort and also improve human's safety. But different traffic condition we need to analyse the effect of ADAS on an individual basis and also group basis [3]. Also, the different environment condition such as fog various research works has done for visibility improvement algorithm and image processing techniques [3][47][48][49]. In the last decade, the reputations of the Internet of Things, several research struggles shows the growing IoT application scenarios. The availability of heterogeneous devices, spanning from a smartphone and a wireless sensor, network enable physical devices such as radio-frequency identification etc. made a platform for globally integrated communication [50][51]. [52] L. Foschini et al., 2011 proposed a pioneering architecture for the combination of WSN with IP multimedia system. This opens the door for context-aware application such as healthcare, environmental monitoring, and so on. The key [53] components of this architecture are WSN/IMS gateway which provides an interface between WSNs and IMS, and the IMS which is liable for the controlling of context information in the core network. The integration of WSN and IoT are well-matched for durable environmental information acquisition [4]. The generic based WSN can be used in the wide application of IoT. The examples of IoT application like environmental monitoring, which requires low deploying cost, multiple nodes, easy distribution, and less maintenance. These features are well-matched with integrated WSN capabilities. The latest development of smart cities, which helps to make improvements in quality of life is further a new research scenario in IoT application. [5] P. Bellavista et al., 2013 proposed a method for fast collection of urban data by integrating WSN, Mobile Ad-hoc Networks and IoT for smart city scenarios. The integration of WSN with IoT seem different security requirements, like making a secure network set up amongst the sensors and internet based host. [54] F. Li & P. Xiong, 2013 proposed a heterogeneous online/offline signcryption scheme for providing the network security between the sensors and internet host.

Table II: ITS Application Problem And Solution

Year	References	Application	Problem	Solution
2022	[82]	VANET	Routing	Enhancing Vehicular Ad Hoc Networks' Dynamic Behavior by Integrating Game Theory and Machine Learning Techniques for Reliable and Stable Routing
2022	[81]	IOV	Tracking	Circularly Polarized Cross Dipole Antenna
2022	[80]	VANET	Clustering	Modularized hypergraph clustering scheme model for stable VANET
2021	[79]	VANET	Clustering	Hypergraph-based dynamic stable clustering scheme model for vehicular ad-hoc networks (VANETs)
2021	[78]	VANET	Energy Sharing Among Electric Vehicles	Vtrust: An iot-enabled trust-based secure wireless energy sharing mechanism for vehicular ad hoc networks
2021	[77]	VANET	Vehicular Cloud Management	RSU-Aided Cluster Based Vehicular Cloud Architecture
2020	[76]	IOV	Connectivity	Layer Communication Model
2020	[75]	IOV	Network Topology	Vehicles Trajectory Clustering
2019	[74]	VANET	Collision And Delay	Demand Aware Media Access Control Scheme Based On Multi-Channel Cooperative Cooperation
2019	[73]	VANET	Channel Utilization	Optimized Link State Routing Protocol with Minimum Multi-Point Relay Selection Algorithm

2019	[72]	VANET	Broadcasting Overhead	Robust Multi-Point Relay Selection Procedure With Optimized Link State Routing Protocol
2018	[71]	Urban VANET	Routing Delay	Cross Layer Cooperative Routing Protocol With IEEE 802.11P
2018	[70]	Highway VANET	Reliable Routing	Collision Aware Opportunistic Routing Protocol
2018	[69]	VANET	QoS Of 802.11P	Adaptive Transmission And Clear Channel Assessment Power Scheme
2017	[68]	Traveler Information	Effective Routing	FAVOUR algorithm
2016	[67]	ITS	Automated ITS	Cooperative Vehicular Techniques
2016	[66]	VANET	Broadcast Overhead	Beacon Information Independent Routing Algorithm
2015	[40]	Vehicular Control Technologies	context-awareness in VANET	Decentralizing the information processing in VANET
2014	[38]	Traffic Flow control	Traffic congestion	Balancing Lane Use with VMS

IV. DISCUSSION

Different kinds of research papers are go through in this study which contains conference papers, articles, workshop, preceding and journals. Many of these focus on routing problem in WSN, Vehicular communication technologies and traffic flow control strategies in ITS. A sample of proposes routing protocol that consider few constraints of WSN is shown in Table-I. It is strong that numerous hard work have been made to improve the lifetime of WSNs through a diversity of energy efficient approach. It is also give the idea that network lifetime of WSNs strongly reliant on data aggregation. Also scalability of networks effect the overall performance of a network distribution. Indeed, Energy-efficient routing protocols and data aggregation scheme directly influence network latency. For example, we can see that energy-efficient routing protocols can improve the robustness by using sink relocation that provides balanced distribution in case of large energy depletion

Furthermore, In Table-II (which represents the application specific problems) provides of solution proposes in the literature to satisfy application objective. Road safety, traffic flow control and reliable communication are the important requirements that can be used to classify ITS applications based on their primary purpose. However, road safety and traffic flow control are not completely separated from reliability of network. For instance, a collision of two or more vehicles can lead to a traffic jam. The information of this event conveys a safety warning for nearby drivers for event awareness. The same information broadcast in ITS network with reliable infrastructure which may be used for different purposes. For example, we can use this information for road congestion management which can provide drivers with the best routes to their destinations and also determine the best time schedule for smooth traffic along the overall routes.

V. CONCLUSION

The main objective of designing the routing protocol is to increase the lifespan of the network. That is possible only when sensor nodes having a long operating time. In this paper, we conclude the unique characteristics, design objective, routing protocols, and presented the requirements of the WSNs for ITS. Here, we consider a number of categorization criteria, including network heterogeneity, path redundancy, data processing, location information, and path redundancy. These standards aid in reviewing a routing protocol sample. Finally, we summarized and made a table that includes the different application of ITS with their problems. In this table we also reviewed the required solution. Road safety, traffic flow management, and dependable communication are crucial criteria that may be used to categorise ITS systems according to their main usage. Road safety and traffic flow management are somewhat related to network dependability, though. For instance, two or more automobiles colliding together might cause a traffic bottleneck. The information about this incident offers a safety message for oncoming cars to be aware of the incident. Information that is broadcast through an ITS network with dependable infrastructure and may be utilised for a variety of applications. Confidently, by impression this paper, the beginners can better understand of routing protocols and countermeasures in WSNs. Also, the researchers can be motivated to design intelligent infrastructure, smarter vehicles and more robust secure information system.

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