Intelligent Public Transport Prediction System Using Wireless Sensor Network: - A Survey

Hundaol Bedada Regesa[1], Gelane Diriba Chala[2]

[1]Department of Computer Science and Engineering, College of Electrical Engineering and Computing, Adama Science and Technology University, Adama, Ethiopia

[2]Department of Information Technology, Bule Hora University, Bule Hora, Ethiopia

Abstract

Wireless Sensor Networks (WSNs) consist of a large number of self-powered, low-cost sensing devices that are interconnected through wireless ad hoc communication technologies. These networks enable real-time data collection, processing, and transmission across distributed environments, making them highly suitable for dynamic and large-scale applications such as transportation systems. In recent years, the integration of WSNs into Intelligent Transport Systems (ITS) has gained significant attention due to their ability to enhance traffic monitoring, management, and prediction. This survey paper presents a comprehensive overview of an Intelligent Public Transport Prediction System based on Wireless Sensor Networks. It discusses the fundamental concepts of WSNs, including their architecture, communication protocols, and network topologies, and examines how these components are applied in transportation environments. The study highlights the role of WSNs in collecting real-time traffic data such as vehicle density, speed, travel time, and environmental conditions, which are essential for accurate prediction and decision-making. Furthermore, the paper explores various applications of WSNs in public transport systems, including bus arrival time prediction, congestion detection, route optimization, and passenger information systems. It also reviews different design approaches and models used for traffic prediction, emphasizing the integration of data analytics and machine learning techniques to improve system accuracy and efficiency. In addition, this survey addresses key challenges associated with WSN-based transport systems, such as energy efficiency, network reliability, data latency, scalability, and security concerns. Potential solutions and recent advancements in communication technologies are also discussed to provide insights into future research directions. Overall, this paper demonstrates that the integration of WSNs into intelligent public transport prediction systems can significantly improve the quality, efficiency, and safety of urban mobility, while also contributing to sustainable transportation development.

Keywords: Wireless Sensor Networks, Intelligent Transport Systems (ITS), Public Transport Prediction, Traffic Monitoring, Machine Learning

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1. Introduction

With the fast development of automotive industry as well as Information and Communication Technology (ITC), our daily lives have been largely influenced and people tend to spend more and more time relevant to vehicles. It can be foreseen that the next generation transportation system will become a more powerful system by utilizing existing communication, network and computer infrastructure.

2. WSN-Based ITS Applications

WSNs are an interesting alternative to other technologies traditionally used for monitoring. Their use entails low installation and maintenance costs and enables the development of distributed collaborative applications, thus not limiting their functionality to the mere acquisition of data. In addition, WSNs can be used in conjunction with other technologies making more complex applications possible. The functions performed by these applications fall into different categories: (a) traffic safety, (b) traffic law enforcement, (c) traffic control, and (d) smart parking applications. In addition, it is also possible that WSNs participate in other applications conducting tasks such as information retrieval (e.g., local services discovery) or entertainment; their contribution to these applications is limited though, as they are in principle less appropriate than other technologies, thus restricting their use to situations where these more suitable technologies are not available [2].

2.1. Traffic Safety Applications

Traffic safety applications deal with the prevention of accidents. In order to fulfill this purpose they make sensor devices work proactively to warn drivers about potentially dangerous situations, such as the presence of obstacles, animals, adverse road conditions (ice or water) and vehicles either stopped (queue-end warning) or driving in the opposite direction (overtaking assistance, wrong-way driving warning). The collaboration among these devices enables to notify drivers of events beyond line-of-sight, thus increasing the available time of response. There are two ways of approaching these applications, although it could also be possible to develop applications that use a combination of both. In the first approach, upon the detection of the arrival of a vehicle by a static sensor node, the latter activates the subsequent static nodes in order to obtain the condition of the following stretches of the road. This approach has been employed by different applications to support overtaking assistance [3] or animal detection by checking that, correspondingly, there are no vehicles or animals present within a safety zone defined by the application.

The second approach consists of making road information available to nodes before vehicles reach them. This implies that, whenever some data of interest is acquired, it is disseminated within a certain area so that, later, they are gathered by passing vehicles (store & forward scheme). This approach is well suited for the detection of non-ephemeral events, such as the occurrence of dangerous road conditions. In this category of applications it is common to find collaboration between WSNs and VANETs, which helps spreading information and prolongs the lifetime of static nodes. As an example, [4] suggests emplacing static nodes at the beginning of each road, which allows all vehicles accessing it to learn in advance about the conditions of the road (previously gathered by other vehicles). A denser deployment is used in [5], in which WSNs monitor the road and VANET disseminates the information either to other vehicles traveling in road segments without WSN infrastructure or to distant static nodes which will warn drivers in the absence of other vehicles.

WSN can also enable real-time optimization and control of various resources, where resources vary from one application domain to another. Waste management, traffic control, smart parking, water/irrigation management, and guided navigation are a few applications where resources can be optimized and controlled efficiently via WSN. Depending on the application, WSN can then reduce operational costs, augment crops productivity, and improve system reliability and performance [2].

2.2. Traffic Law Enforcement Applications

Traffic law enforcement applications can be considered as a special case of traffic safety applications, since one of the final goals of traffic laws is to increase safety. Currently, traffic law violations are usually detected and put into effect when a police officer or a traffic enforcement vehicle is nearby. WSNs though, offer permanent monitoring of the locations where they are deployed, enabling to automate the process of reporting infractions. Some laws which can be supervised are speeding, illegal parking, going through red traffic lights, unauthorized use of bus lanes or access to restricted or congestion charge areas; yet the first two are those typically included in applications so far. Applications such as [6] detect speed limit violations with high precision through the collaboration between adjacent nodes. They rely on cameras triggered upon the detection of the infraction, whose photographs are sent to a Traffic Management Center (TMC) where they are processed and stored. In addition, it is also possible to warn drivers by means of Variable Message Signs (VMS) before proceeding to fining. Illegal parking is also detected by [6] using sensor nodes placed next to curbs which, in turn, after warning through a loudspeaker, activate a camera that takes a picture of the license plate number of the vehicle. Another application related to traffic law enforcement is post-accident investigation, performed in order to determine responsibilities after an accident. WSNs deployed along the road for a particular purpose get data that is used within a short period of time to fulfill this purpose, e.g., traffic safety. However, it is also possible to permanently store this information and use it later to investigate the causes of the accident (car accident forensics). Although WSN devices are, by nature, constrained devices, they are less and less constrained in storage capacity and can thus hold an important amount of information.

2.3. Traffic Control Applications

Traffic control involves applications directing vehicles within a road network. These applications consider a road network as a graph composed of intersections (vertices) and road segments (edges), with sensor nodes deployed at and along both of them. Sensor nodes along segments are used to measure the traffic flow in roads, obtaining information such as vehicle density, speed, formation of platoons or distribution of vehicles according to different categories. Sensor nodes at intersections, in turn, are responsible for making the appropriate decisions on how to direct traffic based on the information provided by the sensor nodes along the road. It is also possible to make these decisions in TMCs; however this is a less often explored possibility which implies the transmission of information to a centralized TMC through an external network [2]. WSNs can also be very useful in traffic monitoring and control. It enables quick collection of real-time traffic information that can be used to avoid traffic jams, report accidents, report road constructions, and reduce fuel consumption. Traffic information can be sensed and collected by designated sensors, or by participatory sensing devices (e.g., smart phones and smart cameras) to monitor roads and traffic conditions in cities [1] [2].

2.4. Smart Parking Applications

Smart Parking: Using WSNs, one can provide real-time information about parking availability to locate parking spots faster and more efficiently, which saves time of car drivers and reduces energy consumption. This can be achieved by quickly identifying and reserving a free parking spot in the vicinity of the drivers' final destination [2]. The lack of parking spaces in cities is a concern which leads to illegal parking, congestion due to low speed driving and long searching times suffered by drivers. WSNs are useful for the deployment of smart parking systems as a substitute of more expensive wired sensors [1].

2.5. Requirements

The success or failure of a WSN-based ITS application is decided by many factors. As regards the design of the application, there are some of them which, to a greater or lesser extent, must be satisfied. Some of these are as follows:

- **Low cost**. In order to be an attractive alternative to other technologies, a WSN-based system must be cost-effective. This implies reducing the costs of the deployment and maintenance by using as few devices as possible and assigning them the minimum set of functionalities required, reserving more costly functions to a reduced group of nodes.
- **Lifetime**. The deployment of the system infrastructure carries an associated investment. Its benefit will depend on the period of time during which the system is exploited. Given the power restrictions of WSN, this period will be determined by the ability of the network to reduce power consumption and by the use of additional power supply sources.
- **Flexibility and scalability.** A system must be able to adapt to the different situations which are expected under its normal operation. This includes variable traffic conditions and the penetration ratios of smart vehicles in the system. Similarly, it is desirable that a system be versatile enough as not to be restricted to a fixed scenario, making it reusable for different purposes and in different locations.
- **Robustness and fault tolerance**. Sensor nodes deployed on the road are subject to adverse situations such as the passing of vehicles over them and unfavorable atmospheric conditions which may provoke either the failure of the node itself or its malfunction. This imposes the necessity for means of physical protection. In addition, in case of breakdown of single nodes due to harsh conditions or battery depletion, the overall operation of the network must not be affected, which implies providing the network with redundancy or alternative mechanisms to guarantee connectivity.
- **Appropriate Quality of Service (QoS) provision.** According to the function of the system different QoS parameters must be satisfied including reliability (referring to the correct reception of delivered data at the destination), delay and, in infrequent cases, bandwidth. Safety applications are the most demanding when it comes to reliability and delay, since it is crucial to report any imminent danger well in advance. Other applications are less strict as sporadic losses or delays neither provoke accidents nor probably the malfunction of the system.

3. Network Architecture and Topology

A distributed WSN-based ITS application accomplishes four different main tasks: (i) acquisition of information, (ii) data distribution, (iii) data processing in order to plan the necessary actions, and finally, (iv) execution of the appropriate actions. Since these tasks may be carried out independently, it can be considered that they correspondingly define four differentiated subsystems which are present in ITS systems, namely, the Sensing subsystem, the Distribution subsystem, the Decision Making subsystem and the Execution subsystem. In this paper these subsystems have been abstracted in a reference architecture depicted in Figure 2, which is inspired by the architectures proposed in [7, 8]. It is defined by placing the different subsystems at separate hierarchical levels, where each subsystem may interact with its neighbors at the immediately higher and lower levels. The architecture of a particular system will be based on the allocation of these subsystems into tiers of distributed and potentially heterogeneous devices.

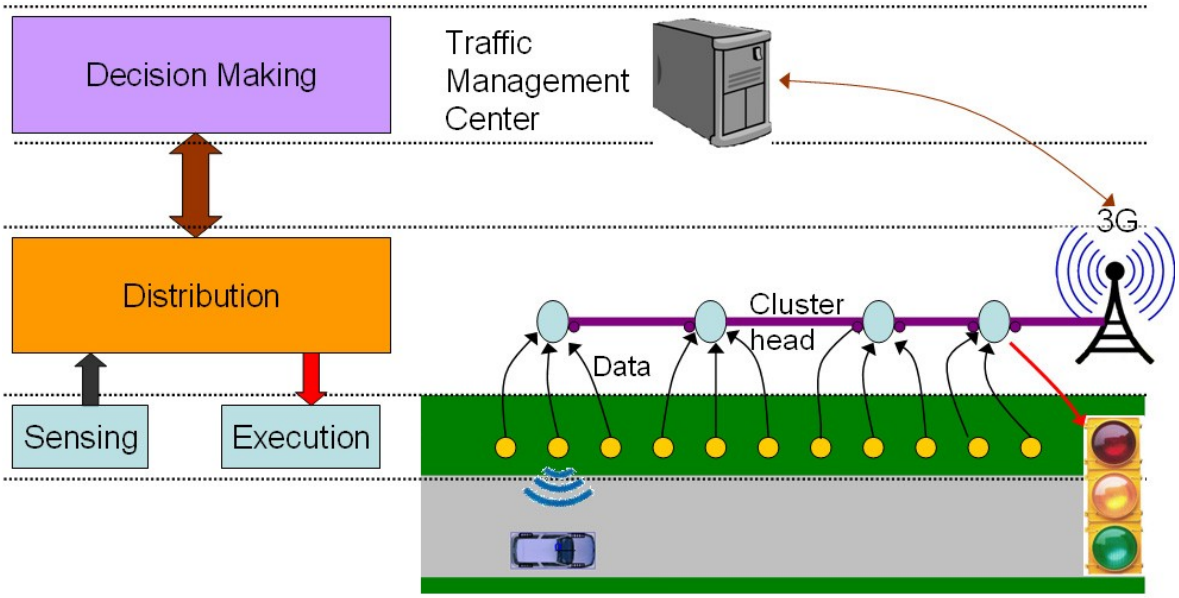

Figure 1 Reference architecture for WSN-based ITS applications

3.1. Sensing Subsystem

The Sensing subsystem is composed of all the devices in charge of acquiring relevant information mainly relative to traffic and road states. In a WSN-based ITS application, not necessarily all the devices use WSN technology, allowing a distribution of tasks among devices using different technologies. However, as regards the acquisition of data, WSNs are the prevailing technology of choice. Consequently, the implantation of the sensing subsystem consists of the deployment of one or several WSNs throughout the observation area (roads or parking lots), which detect vehicles through their sensors and optionally communicate wirelessly with them. After observing how different applications have dealt with the deployment of these WSNs, it was noticed that they follow some basic topological patterns which determine important properties of the system such as lifetime, costs and functionality. WSN nodes are divided into groups following a similar outline, and the deployment consists of a composition, typically homogeneous, of these groups of nodes. Therefore, they can be considered as the building blocks of the sensing subsystem. It should be noted that, in addition, the nodes forming these blocks may propagate information within them, but this should not be confused with the Distribution subsystem. Data propagation in the Sensing subsystem is restricted to local areas, aimed at extracting information from the block/group (towards a sink node) or enabling collaborative processing with nearby nodes. Below, the different topologies which were identified, shown in Figure 3, are introduced:

- **Mesh Topology**

A mesh topology presents a generic case used in applications concerning many WSN domains. As a result, there are many communication protocols available which are intended for the creation of self-forming and self-healing (fault-tolerant) networks, performing many-to-one and one-to-many communications. Consequently, this topology is adequate for applications which need to deploy their nodes in a grid layout (e.g., parking lots [9]), not necessarily regular, and which deliver their data to a central sink for decision making. However, this topology complicates the development of collaborative applications since the network self-forming mechanisms do not allow to control how nodes establish links between them.

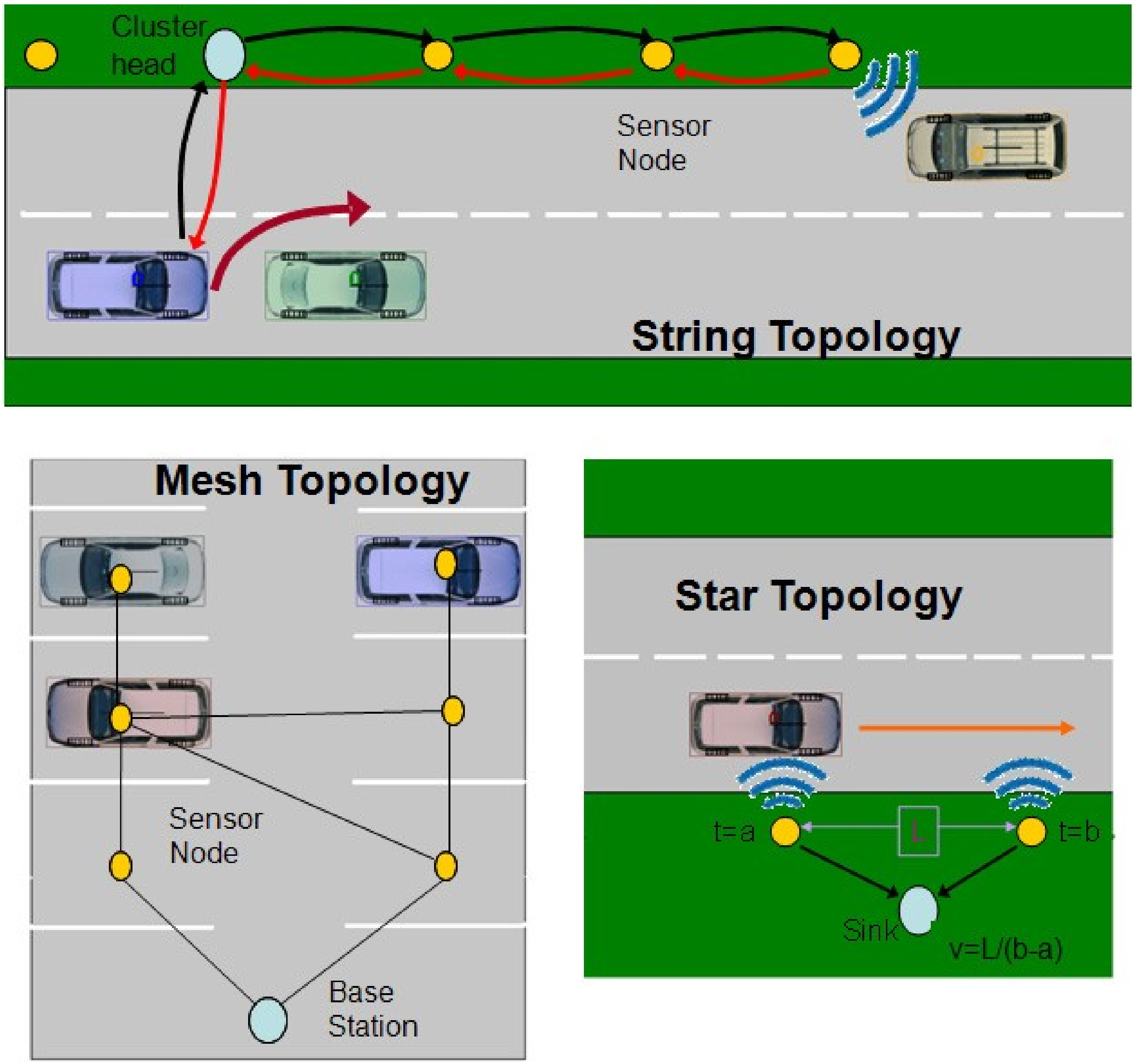

Figure 2 Sensing topologies and examples: (a) String topology, overtaking assistance, (b) mesh topology, parking lot, (c) star topology, speed detection.

- **String and Cluster String Topologies**

Linear or string based topologies arrange static nodes in a row parallel to the road, leading to an important reduction in the complexity of the routing protocols, since every node only has to decide in which direction to forward. This implies the use of a 1-dimensional geo-routing policy with simple addressing schemes which enables point-to-point communications between nodes, thus simplifying the development of collaborative applications. For example, a node detecting a vehicle can start the collaboration with neighbor nodes just by indicating that it intends to share the event with nodes up to a determined hop count. Two different alternatives fall into this group of topologies, the uniform string topology and the cluster string one [3]. The difference between them lies in the allocation of tasks among the nodes. In a uniform string topology all the nodes have similar hardware resources and perform comparable tasks regarding vehicle detection and routing.

- **Star Topology**

In the star topology a few sensor nodes are set around a sink. Its advantages are simplicity and the avoidance of routing schemes, which helps to preserve energy. Unidirectional communications are assumed to deliver information from sensor nodes towards a sink for data analysis. In spite of potentially offering less functionality, they enable additional power savings since sensor nodes are not the destination of any message and, therefore, they do not need to periodically power up their radio and wait for incoming messages. Consequently, these are the most energy-efficient cases of all, especially the former. However, the placement of nodes is limited to the area of coverage of the sink.

❖ **Barrier Topology**

The barrier topology deploys several nodes transversely, one per lane, across the road (see an example in Figure 3). It can be considered as a particular case of star topology, which inherits all of its characteristics. Since it is a very simple topology, its functionality is restricted. However, it allows to obtain the number of vehicles passing a determined point of the road and it is therefore quite useful in applications which need an estimation of the traffic load.

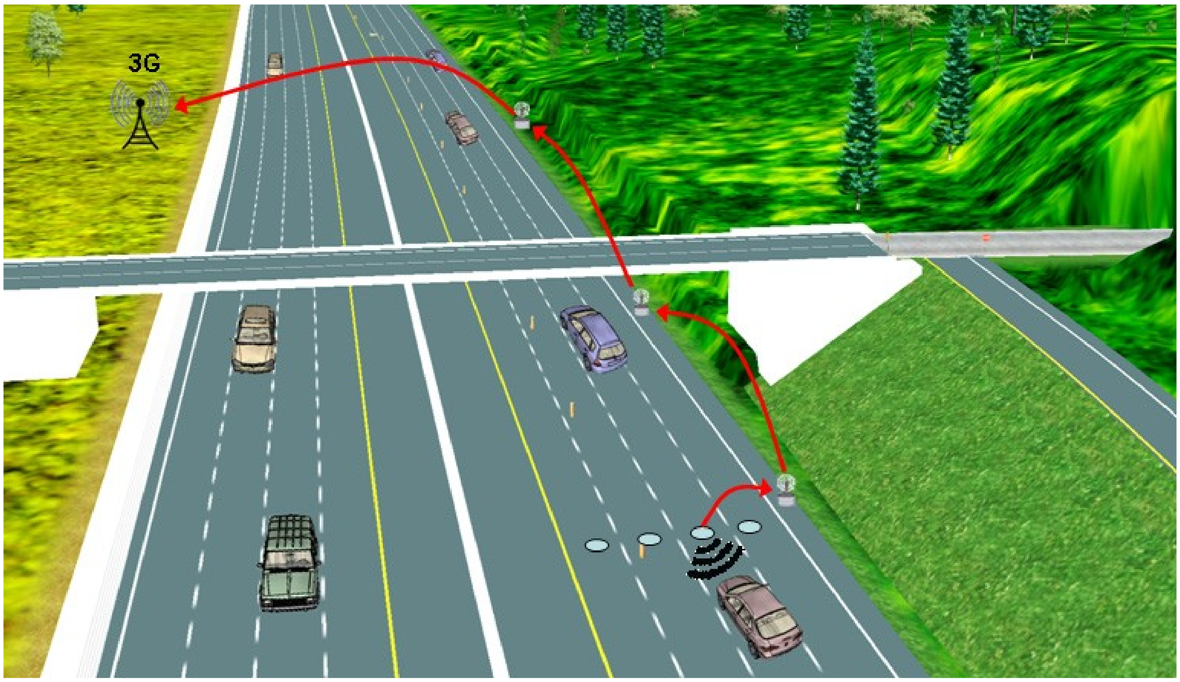

Figure 3. Distribution subsystem based on the availability of cellular networks.

❖ **Vehicular Sensing**

In addition to obtaining traffic and road information by means of static nodes, it is also possible to use vehicles for this purpose. In this respect, measurements taken from the different sensors installed onboard vehicles, as well as information about the presence of other vehicles, can be transmitted via radio to roadside nodes. Therefore vehicular sensing requires static deployments of one of the arrangements above. The fact that a vehicle itself announces its presence by means of RF transmissions, which henceforth will be denoted as active vehicle detection [5], allows that only vehicles that are able to interact with the system will be detected by the roadside deployment. On the contrary, non-equipped vehicles are disregarded by the system, which is a problem for applications requiring a detailed knowledge of the traffic state.

3.2. Distribution Subsystem

The Distribution subsystem is responsible for exchanging information between the different subsystems of an ITS application. In a tiered architecture such as the one in Figure 1, it is placed in a central position, receiving communication requests from all the other subsystems and serving them accordingly.

3.3. Decision Making Subsystem

The Decision Making subsystem (DMS) is in charge of planning the necessary actions in order to achieve the objectives of the system. The tasks which are assigned to this subsystem can be divided into three different groups. The first of them comprises tasks aimed at data storage and preprocessing. It deals with the huge amount of data which arrives at the subsystem, filtering and storing only relevant information and subsequently accessing to it. The second group handles traffic information from different sources and processes it according to the aim of the application. Finally, the third group of tasks is responsible for addressing control commands as well as for managing the network. The DMS can be executed at different levels. In a top level it can be implemented at centralized TMCs. This implies that all data gathered by the sensing subsystem is sent, via the Distribution subsystem, to the DMS, which must support an asymmetric data flow. The main advantage of this approach is the possibility of performing complex calculations over a great amount of information. Conversely, if only simple processing is to be applied, the DMS can be distributed among the sensor nodes. This enables performing simple collaborative algorithms between neighbor nodes which allow the execution of real-time traffic safety applications. Finally, another solution is the use of smart devices (smartphones, etc.) in vehicles, which may receive raw data from road networks and use them, for example, to plan routes.

3.4. Execution Subsystem

The Execution subsystem performs the necessary actions which foster changes in the traffic flow according to the objective of the ITS application. It is mainly composed of devices providing visual and acoustic stimuli to drivers, though others aimed at vehicle automation would also pertain to this subsystem. Different equipment may be used. Traffic lights or Variable-Message Signs installed along the roads are attractive options which provide strict control and adaptability to different situations, respectively. They offer the advantage of being widely adopted road infrastructures, suitable for reuse in ITS applications, which help reducing deployment costs. The use of panels attached to the sensing nodes is another possible solution; nevertheless power supply restrictions of unwired nodes limit their application to small panels or informative leds. Finally, the employment of in-vehicle systems offers, on the one hand, the possibility of presenting customized information for every vehicle and, on the other hand, the chance to use acoustic signals and messages that diminish distractions while driving. In addition, the information from the road systems can be integrated into In-Vehicle Infotainment (IVI) systems, for example, for its fusion with digital maps or other information services (transport timetables, weather forecasts, etc.).

3.5. Network Architecture Classification

The architectures of real ITS systems can be obtained by mapping the subsystems depicted in Figure 1 onto physical tiers of devices. This leads to largely differentiated systems according to the way that it is done. Two top level decisions should be made; firstly, a flat vs. a hierarchical network must be selected and, secondly, for the latter case, a homogenous vs. heterogeneous use of wireless technologies. The next sections describe different alternatives which can be found in any of these cases.

3.5.1. Flat Networks

In flat networks all the deployed nodes play the same role and therefore perform the same tasks. ITS systems employing them are single-tier systems where a roadside WSN carries out sensing, distribution and, if required, collaborative decision making tasks. Conversely, centralized decision making and execution tasks, due to the limitations of WSNs, are undertaken by other external subsystems. The main advantage of these systems is their simplicity. Nodes with higher complexity are not needed since, on the one hand, it is not necessary to deal with issues related to the interconnection of different technologies and, on the other hand, routing protocols in flat networks are usually simple. However, flat networks have an important disadvantage in what regards scalability. As the number of nodes in a network increases, the gateway node and those around it are subject to an overload which can either degrade the performance (by means of information packet collisions and increased latencies) or force the use of a longer active period in the nodes, thus increasing power consumption.

The lack of scalability of this pattern restricts its use to small areas. As a consequence, it is mostly used for smart parking applications [10], in which sensor nodes are installed on every parking slot forming a grid layout which suits the use of generic routing protocols for flat networks. However, it is also possible to find traffic applications using flat networks with string sensing topologies. Their use is feasible in applications aimed at controlling isolated hotspots on the road, not requiring a centralized and distant DMS, for example in overtaking assistance in dangerous locations, since it is only necessary to share events with a few neighbors.

3.5.2. Hierarchical Networks

Unlike flat networks, these networks make use of a hierarchical distribution of tasks among nodes. The network consists of heterogeneous nodes where the most powerful one performs the most demanding tasks and the less powerful nodes are reserved for the less challenging ones, thus saving as much energy as possible. This can be accomplished by using simple schemes. The simplest approach is the one used in many traffic control applications, in which one or few sensor nodes are responsible for traffic detection, while nodes at intersections control traffic lights. However, hierarchical networks are able to offer a more important benefit when they are applied to larger systems. A well-known class of hierarchical networks is clustered networks, which stand out thanks to their scalability. They are based on grouping nodes into clusters where one of them is selected as the cluster head, which will present the services offered by all cluster nodes to the external devices. This results, as it was stated, in saving costs and energy, since most of the nodes implement only lightweight functions and a few of them, the cluster heads, require a greater investment in more powerful devices and in larger power units and solar panels [3]. Scalability is provided by increasing the number of clusters, which does not increase the complexity of each cluster. Consequently, simple routing algorithms can be applied within the cluster, being single hop star topology a feasible option. This can be useful not only for traffic applications but also in parking applications, deploying a cluster star network formed by the composition of different groups of nodes with a star topology which transmit to a central base station. If scalability to wider areas is required there is the possibility that the cluster heads self-organize into a multi-hop network that delivers information to farther points. The result is a two-tiered system where constrained cluster nodes compose the sensing tier and more powerful cluster heads pertain to the distribution tier, as can be seen in the example shown in Figure 3. This permits sharing road information with distant nodes in order to warn drivers timely as well as communicating with a distant DMS since a tiered architecture allows separating delay sensitive operations (speed measurement, detection of dangerous vehicles) from delay insensitive operations (storage at the DMS). In the latter case, when a distant DMS is present in the system, it can be considered as the third tier of it, in charge of the centralized decision making [7].

3.5.3. Heterogeneous Networks

Heterogeneous systems combine several wireless technologies to facilitate the development of more effective applications. Since every wireless technology offers distinctive advantages and disadvantages, a heterogeneous system seeks to focus on the advantages of a particular technology to compensate the drawbacks of another technology also employed in the final system. For example, WSNs have their main weakness in their constrained use of the scarce available energy. However, this is a minor issue in VANETs. On the contrary, achieving high technology penetration rates in VANETs in order to boost performance is not straightforward, but the installation of WSN nodes on selected roads is a simpler task. One can take advantage of the composition of heterogeneous technologies, which results in the devices of each technology arranged in their own tier, assigning sensing and distribution tasks to either of the tiers.

The other category of heterogeneous applications is the VANET-centric applications. In this category the WSNs are used to improve the performance of existing VANETs [4]. They assume that VANETs are established but that they are split into different isolated partitions, which consequently cannot share information. WSNs can solve this problem in an analogous way as RSUs do, i.e., storing information from a partition and delivering it to subsequent partitions when vehicles arrive at the WSN location. However, RSUs are scarce and expensive equipment. In contrast, simple WSN islands, ranging from a single node to a barrier of them, are a cheaper solution for those locations where RSUs are not already available or cost-effective.

4. Road traffic

Nowadays, there are different system deployments that allow control road traffic. We can find a lot of approaches from point of view of transmission and reception of information:

4.1. Data acquisition stations and inductive coils:

In these kinds of data acquisition systems to get data from road traffic is carried out by means of a few stations. These stations are placed in the protected boxes that we can see in the wings of the roads. Inside of these boxes, between other components there are a few detectors that receive the pulses from the inductive coils placed under the floor. The inductive coils allow detecting the presence of vehicles over the road [1]. With this kind of systems (two coils placed successively) it is possible to get different data, as intensity, activity, congestion, average speed, average distance between vehicles and detection of vehicles driving in opposite sense [1].

4.2. Sing posting System:

The objective of these systems is to show information about all what is happening along the road to the drive. They are made by digital panels which show information needed for the safe and fluid traffic on the road. They connect to the most close data acquisition station by means of optical fiber. These data are transmitted to the Control Center in order to the users could always know what happens.

4.3. Weather stations:

The deployment of weather stations is also usual in order to known and to prevent risky situations. These stations are equipped with a huge variety of sensors as thermometers, barometers, anemometers or hygrometers.

4.4. Tele-vigilance system:

The monitoring center can get knowledge about all what happens in anywhere of the road at real time by means of cameras deployed along the road. It helps to activate the emergency services in a few minutes. The video signal can be transmitted to the monitoring center by means of proprietary or TCP/IP protocol stack using Ethernet transvector and optic fiber as transmission mean.

4.5. Monitoring Centre:

It is the place where the management of data got from devices deployed along the road is performed. The monitoring room is connected to the communication network that includes the data acquisition stations. These stations transmit data using optical fiber switches between other devices.

5. WSN Application Design

WSNs are a powerful technology to implement and deploy distributed sensing applications. However, during the development of WSN-based ITS applications, a set of design aspects may have a decisive influence on the behavior of the system. This section is aimed at discussing the main design concerns that arise to satisfy good performance and long system lifetime. The unavoidable issues that the designer must face are the placements of the nodes, the duty cycle and the message delivery delay.

6. Communications

The networks deployed in order to support kinds of data acquisition systems are usually built with optical fiber (mono mode/multimode). The optical fiber networks are the base over which different protocols are working: Ethernet in link level, or TCP/IP in network and transport levels, as well as the applications needed in the higher level [1].

6.1. Medium Access Control

The Medium Access Control (MAC) layer provides link-level data addressing and access control mechanisms to the physical medium (radio) shared by nodes in a multi-point network. The design of MAC protocols for WSN is different from that for other wireless networks since it is mainly focused on power conservation, which implies finding a trade-off between different metrics such as latency and throughput in order to extend the network lifetime. In the scientific literature, many MAC protocols suited for WSNs can be found as well as survey works according to different purposes, including [12], where real-time MAC protocols are considered, and [11], which deals with energy-aware protocols.

The focus of this work is on the WSN tier of the system. The approach which has been taken to review how both existing (general purpose) and specifically designed MAC protocols apply to ITS scenarios follows the classification of protocols proposed in [11] because the different categories considered have an important impact on the performance of the system. According to the classification, on a top level we can differentiate between (i) unscheduled or random protocols, where nodes operate independently; (ii) scheduled protocols, which organize communications in an ordered way, with radio transceivers following a coordinated scheduling of their duty cycles; and (iii) hybrid protocols, which combine different scheduled and unscheduled techniques. In addition, sub-classifications for each one are also presented, where it is interesting to remark that scheduled protocols may be divided into contention and contention-less based protocols.

Unscheduled protocols are popular in the WSN domain because they do not require neither clock synchronization among nodes no global topology information. Nevertheless, these protocols may suffer higher rates of packet collisions since they usually do not provide any means for avoiding them, apart from carrier sensing. In an ITS scenario they provide two important advantages: (a) dynamic node joining, which is very useful in ITS since it facilitates communication with moving vehicles, and (b) adaptability to changes in topology.

Regarding scheduled protocols, these are more complex protocols which usually need control messages in order to maintain synchronization and coordinate the radio transceivers active period according to different strategies. This is not an important problem if these protocols are used in road static deployments. However, it may become a serious issue if these protocols are considered for the vehicle to road infrastructure communications, given the limited communication time with travelling vehicles and possible packet losses.

6.2. Routing

Many routing protocols have been designed specifically for WSN where energy saving is the primary concern. Routing in VANET, on the contrary, has to deal with the mobility of vehicles which produces constant changes in the network topology. Routing in flat networks is totally dependent on the selected topology for the sensing subsystem. This also applies to intra-cluster routing in clustered networks. In the mesh and the string topologies are able to perform multi-hop routing. The rest of topologies instead rely on direct point to point communications with a sink node. It is remarkable the considerable power savings that these topologies may achieve if they use unidirectional communications, i.e., the detector nodes merely detect events and notify the sink without receiving commands from it, given that detectors' transceivers may be in sleep mode for extended periods of time, until the detection of an event. Mesh topologies, mostly used in smart parking applications, can be routed according to many different fashions and protocols which are out of the scope of this paper. However an important consideration must be made. The aforementioned disruption of communication links caused by vehicles parked over sensor nodes deployed in parking lots produces bursty packet losses, with high time correlation but low spatial correlation. As a consequence mechanisms based on acknowledgements and retransmissions are not appropriate for reliability.

7. Future Work

Resource management issues in Intelligent Public Transport Prediction System using WSN are far from being solved. Some of these research challenges are as follows.

- **Sensor availability and mobility**:

One source of challenges specific to Intelligent Public Transport Prediction System is the nature and characteristics of the sensory devices (i.e., sensors, actuators, and SANs). In general, these devices have very limited computing and energy resources, and may only have opportunistic network access. Their locations and trajectories may not be known or even predictable, making it too difficult to build robust and reliable physical SANs. It could even be impossible to perform a task; e.g., when the sensing task is to report temperatures in a location where no sensors are available, this task cannot be performed. Some applications may even request that sensing be performed along some specific trajectory/path, requiring sensors to follow the specified path in order to perform the requested task successfully. The nature of sensory devices, which constitute an important set of CARS resources, gives rise to new resource management issues that need to be addressed.

- **Customer-provider resource allocation:**

There has not been much research focus on developing selection algorithms that can find best customers-cloud paths. Path selection algorithms should consider performance parameters like reliability, bandwidth, connectivity, etc. In addition to optimizing path selection, these algorithms can be used for balancing customer request loads to optimize cloud performance.

- **Troubleshooting:**

In traditional networking paradigms, IT teams can easily identify and diagnose failures and performance related problems. Now due to the complexity and to the large number of components involved in such systems, it can be too difficult to troubleshoot technical problems. When designing these systems, it is important to make sure that maintenance procedures are incorporated at an early design stage so that maintenance and troubleshooting can be easily done during system operation.

- **Architectural considerations:**

There is a need for a comprehensive architecture that identifies the different entities and components of Intelligent Public Transport Prediction System using WSN systems, defines their functionalities and responsibilities, specifies their interfaces and interactions, and gives different entities a means to specify regulatory policies and express requirements and preferences.

8. Conclusions

This paper presents a survey of application of Intelligent Public Transport Prediction System Using Wireless Sensor Network. As it has been shown, WSN is a technology which may have a relevant role to Intelligent Public Transport Prediction System, enabling cost-effective and accurate solutions with a wide variety of applications in driving safety and traffic control as well as in parking management. Its contribution is not merely about sensing the environment but about making advanced collaborative Intelligent Public Transport Prediction System applications possible.

The plethora of innovative possibilities that WSNs confer can be further extended if they are complemented with the joint use of other technologies such as VANET or WAN networks, allowing different data dissemination schemes. Therefore, WSNs may take part in heterogeneous Intelligent Public Transport Prediction System in which every adopted technology is used for the purpose it best serves. In spite of this heterogeneity, the design of WSNs for Intelligent Public Transport Prediction System is driven by the same basic premises that any efficient

WSN application must satisfy. This is achieved by finding a balance between, on the one hand, low power operation and processing complexity, and, on the other hand, QoS assurance, which is typically accomplished by applying effective duty cycling schemes and task assignment among the nodes. However, these applications differ from other WSNs applications in the additional restrictions that Intelligent Public Transport Prediction System imposes and in the opportunities they offer. This is mainly due to the mobility of vehicles, subject to relatively high speeds and motion bound by roads. This affects a great number of issues including the detection and estimation of significant features from vehicles, the placement of nodes and the design of routing algorithms, the latter implying a simplification in the development of collaborative applications. In addition, since vehicles pass by sensor nodes in a sequential way, it is possible to develop predictive and adaptive applications as well which correspondingly may learn about the arrival of a vehicle in advance or adapt their action prior to the arrival, thus allowing both power savings and accurate operation.

9. References

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