Wireless Sensors for Analysis Transport Systems

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[1]***Abstract***—The collaborative and low-cost nature of wireless sensor networks brings significant advantages over traditional communication technologies, making them a vital component of the next generation of transport systems, the smart transport grid. In this paper, we explore the implementation of a smart monitoring system over a wireless sensor network. We analyze the opportunities and challenges for distributed signal processing in networks of these sensing elements and investigate some of the architectural challenges posed by systems that are massively distributed, physically-coupled, wirelessly networked, and energy limited. The article is considered an example of the analysis of an actual transport system.

Index Terms—Wireless sensors, transport system, signal processing, sensor node, analysis of actual transport system**.**

I. Introduction

Along with the progress of technologies and communications wireless sensor networks (WSNs) have become one of the independent sensing devices used to monitor physical and environmental conditions and they have thousands of applications in other fields.

The use of a smart grid over WSNs is steadily increasing including wireless automatic meter reading and remote monitoring systems.

Mobile devices have become a tool for some simple communication operations in a multifunctional tool. Modern Android smartphones and tablets feature multiple sensors (sensors) that respond to movement, spatial orientation, environmental parameters (magnetic field, air temperature and atmospheric pressure) and so on. The presence of such sensors makes the mobile device an extremely useful, user-friendly tool. Sensor control occurs in both the entertainment software and applications with a much more serious and professional focus.

This paper shortly introduces the basic attributes of transportation processes from safety, effectiveness, environmental and comfort point of views. Referring to the key technologies used in transportation applications: Sensing, data processing, data transmission etc., the problems of WSNs are also presented. It is possible to state that both of research areas (ITS and WSNs) are using principally comparable technologies for data collection, processing and transmission. This means that WSN technologies are well applicable in the field of intelligent transportation systems (ITS). Certainly, the selection of applications must correlate with specific WSNs characteristics. Finally, it is possible to state that the implementation of wireless autonomous devices in the field of ITS has very good prospects.

This paper analyzes the possibilities of exploiting the technology of WSNs in ITS and gives a detailed description of the sensor nodes used to sense the count of moving vehicles.

II. Smart Grid and Sensors

WSNs are a special wireless network with a number of nodes equipped with embedded processors, sensors, and radios, which collaborate to accomplish a common task in collecting information in a target area. There are several famous projects. WINS of UCLA and Smart Dust of UC Berkeley, which are concerned with the small size node [1], [2]; PAMPS of MIT started to pay attention to the network protocol - low energy adaptive clustering hierarchy (LEACH), which has been proposed in the network layer of WSNs [3] and Mote/TinyOS and Mica family of UC Berkeley became famous public research platforms for many institutes [4], [5]. Subsequently, the application and research on WSNs is booming in the areas of environmental monitoring, advanced agriculture, security, logistic management, and conventional wireless data networks, where the data transfers transparently from the source node to the destination node.

Intelligent networks have revolutionized the current electric power infrastructure by integrating with the communications and information technology [6]. With WSNs, a smart grid enables one to predict and manage. However, the increase in the application of WSNs has introduced new security challenges.

In this paper, we present wireless sensors to instrument roadways for ITS. The sensor package counts the passing vehicles and measures the average roadway speed. Clusters of the sensors can transmit this information in near real-time to wired base stations for use in controlling and predicting traffic.

In this paper we use optical sensors: Key specifications; the range of optical sensors and structural variations [6], [7].

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Optical sensors: Their action is based on the interaction (interrupt passage or reflection) of the generated light beam to the object. The generation of the beam is performed in the transmitter by means of an electronic unit. Typically the receiver is a photodiode or a phototransistor with the same spectral characteristics as the transmitter.

To limit the operation of the receiver to only capturing beams from the transmitter without another light, two solutions are usually used - pulse operation or synchronous detector that only responds to pulses with the frequency of the radiation emitted by the receiver.

Basic parameters: Among the specific parameters of optical sensors is the spatial radiation angle with values between 1.5 and 60°. It, along with the distance to the object (L), determines the diameter of the stain on the object. Another parameter is the sensitivity (S), which is the change in the electrical output signal observed with a power change of 1 W and has a V / W, A / W or W / W dimension depending on the type of signal. The dependence of S on L is called the spectral characteristic. The spectral maximum is the wavelength at which the highest S0 value is obtained.

Range: The range of optical sensors ranges from a few centimeters to 1000 m and the reaction time ranges from several tens of ms to several tens of milliseconds. Assuming that when the object moves away from the sensor, the measured distance is A and when B is approaching, usually A>B and the difference Dl = A - B is the sensor hysteresis parameter. Small D1 values are recommended for subjects with good reflection, as well as for detecting their presence when partially crossing the beam. A large hysteresis is suitable for large objects with little reflection

Structural varieties: Depending on its structure, the optical sensors are divided into several types - reflective, diffuse, fixed focus, and others. For normal operation of the reflective sensors, the beam must be perpendicular to a sufficiently smooth reflective surface. To avoid this too strict requirement, special reflectors or reflective bands are used, which allow operation with beam deflections up to 15°from the perpendicular.

III. IT Solutions for Wireless Sensors Systems

WSNs can be applied wherever we encounter spatially distributed information sources. An interesting application area of WSNs is in traffic monitoring. It is clear that traffic monitoring and management requires information sources that are geographically dispersed over a large area. A comprehensive overview on the state of transport can only be obtained on the basis of the information obtained from a large number of properly deployed sensors. Therefore, the monitoring and management of traffic naturally tends toward the application of sensor networks. Currently, the most frequently used applications of WSNs in the transport field are: monitoring traffic and dynamic routing [7], [8], monitoring and management of parking lots [9] and adaptive control of intersections.

The successful deployment of WSNs in different applications depends on the parameters of the sensor nodes. The most important parameters are:

- The processing power and memory capacity of the sensor
- Low power consumption/long lifetime
- Production cost
- Security
- Fault tolerance and other

Traffic monitoring systems generally try to count, classify, or estimate the speed of vehicles moving on the road.

The integration of emerging information technologies can now provide real-time status updates.

Fig. 1 is a general block diagram showing the possibilities for the realization of the functions in control.

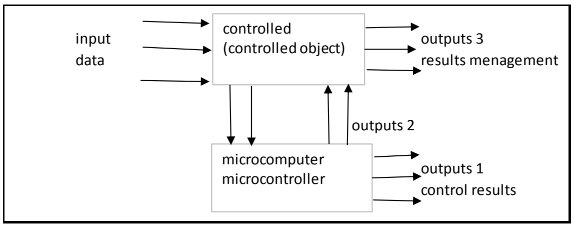

Fig. 1. A general block diagram showing the possibilities for realization of the functions in control.

At the entrance of the controlled (managed) object, the inputs are received, which contain information about the occurring events and the state of the environment. The microcomputing system, through the signals captured in object-specific and process points, evaluates the compliance with the set objectives and produces the corresponding signals. In the information system, these are direct outputs 1 to an indicator and recorder that take into account the results of the control.

Real-time continuous data collection - There are techniques for filtering the sensor data that combine the readings of two or more sensors. These techniques are known as sensor fusion and are based on two approaches:

- The use of a Kalman filter
- The use of a complementary filter

Because of the specific techniques and the need to use specialized mathematical apparatus, the same will not be considered here [10], [11].

The node must have sufficient processing power to process all relevant data and to calculate the results. In the case of a centralized network structure, the node just collects data and sends them to the central unit for further processing. However, it is usually impossible to transmit all the measured data because the data transmission is very energy intensive. Therefore, we try to minimize the volume of transmitted data. It is important to realize the essential part of the data processing at the point of its origin - in the sensor node. The data transmitted to other network nodes should contain only the information essential for problem solving. Basic data preprocessing algorithms thus relate to the methods of information content extracting (compression). Another possibility is to use collaborative signal processing algorithms. These algorithms use the smart distribution of data processing between the different network nodes in order to increase the overall computing power of the network while minimizing the total energy consumption.

Sensors will count the vehicles during peak hours at the busiest junctions. A wireless connection for data transmission is provided as well as a system and applications for back office - server/platform, system and application software, and software. The system should also be used for mobile devices in order to receive timely information from the teams that control it. Vehicle counting in real-time will allow optimization.

Sensors will count road traffic. These sensors will be part of the so-called road management system, which is extremely necessary.

IV. Detailed Description of Sensor Node

Despite a variety of application areas, the basic structure of the node is the same. Each sensor node must be able to perform three basic functions: Sensing the selected signals using appropriate sensors and transforming the measured signals into signals that are suitable for additional processing (most often electrical voltage).

- Adjusting the signal level in such way that the dynamic range of the A/D converters is utilized in the best manner.
- Filtration of the additive inherent and interfered noise from the signal. The useful part of the signal should not be distorted.
- Filtration in order to limit the frequency spectrum of the signal so it is in compliance with selected sampling period (anti-aliasing filter).

Fig. 2 shows the basic structure of the sensor node comprised of the following elements:

T–Transmitter
R–Receiver
MW–Microwave sensor
Logic block.

The logic block transmits an impulse to the counter only when the IR barrier and MW sensor work simultaneously.

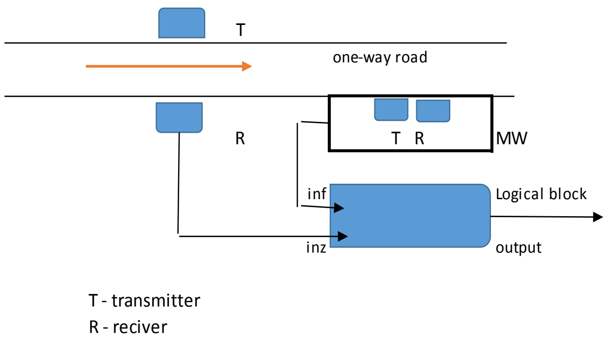

Fig. 2. The basic structure of the sensor node.

V. Analysis Transport System

This example presents a traffic monitoring system implemented using WSNs. The aim was to provide a flexible, robust, low-cost, and low-maintenance wireless solution to obtain traffic-related data that can be used for analysis transport systems.

Each network is composed of nodes and links between the nodes, in which the flow runs with the direction and amount in each node (for unit time). Such a structure is called a directed graph. The task of the network analysis was to determine the flow through each node if it is the only piece of information available (such as, the amount of inflow).

The rule applied in the analysis of flow in the transport network was as follows: The amount of inflow and outflow in each node and the network as a whole, must be uniform.

The article is considered as an example of the analysis of the actual transport system: The amount of flow is the motor vehicles per hour.

Let's look at some of the transport network shown in Fig. 3.

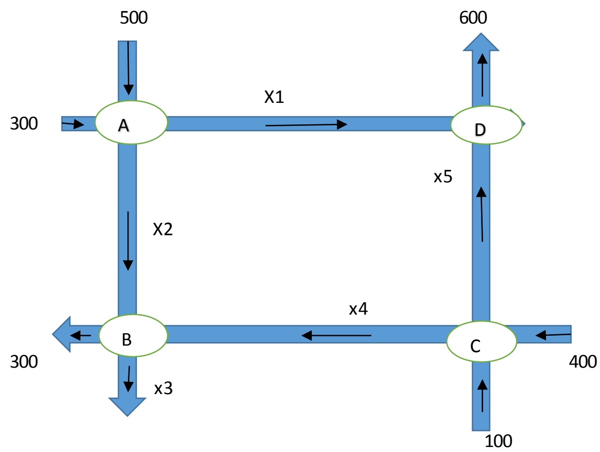

Fig. 3. The transport network.

The amount of flow is on motor vehicles for one hour. For simplicity, we assume that all the streets under consideration are one-way. We will determine the flow through each node with the available data (Table I).

TABLE I: DETERMINING THE FLOW THROUGH EACH NODE.

Node	Incoming flow	Outgoing flow
A	800	x_1+x_2
B	x_2+x_4	x_3+300
C	500	x_4+x_5
D	x_1+x_5	600

The quantity of the incoming and outgoing flows of the whole network, which equals 1300 and x_3+900 respectively, must be equal to each other. We established a system of linear equations with five equations (conditions) for the five unknowns $x_i, i = 1, 2, 3, 4, 5.$

$$\begin{aligned} &x_1 + x_2 = 800 \\ &x_2 - x_3 + x_4 = 300 \\ &x_4 + x_5 = 500 \\ &x_1 + x_5 = 600 \\ &x_3 = 300. \end{aligned}$$

The solution for the above system is:

$$\begin{aligned} &x_1 = 600 - x_5 \\ &x_2 = 200 + x_5 \\ &x_3 = 400 \\ &x_4 = 500 - x_5 \\ &x_5 \in N \cup \{0\} \end{aligned}$$

Now we can analyze the results obtained.

Because the streets are one-way, the value of each stream must be positive. This imposes limitations on the value of the parameter, $x_5 : 0 \le x_5 \le 500$.

Furthermore, since x_5 is a parameter (degree of freedom), the street part to which x_5 corresponds to can be closed without disturbing the entire flow. However, this does not apply to the part of the model corresponding to x_3, since we have $x_3 = 400.$

That is, a fixed value for that stream.

The collected data enables you to solve tasks such as: maximum network speed, minimum network time and more [12].

VI. Conclusions

Transportation is inseparably linked to the life of every person, whether in the form of passenger transport or material transport. To address the new challenges in the area of transportation, a new concept for the next generation of transport systems, the smart transport grid, has emerged.

The management of smart-grid systems will require IT solutions. Pervasive micro-sensing and actuation may revolutionize the way in which we understand and manage complex physical systems. The capabilities for detailed physical monitoring and manipulation offer enormous opportunities for almost every system. IT solutions for creating smart-grid systems and software solutions for analysis will be increasingly used in these control systems.

The smart transport grid is a modern transport system that improves the efficiency, reliability, and safety through automated control and modern communication technologies.

As one of the main objectives, this paper opens up future work in many unexploited research areas applying WSNs in a smart grid to provide an overview of the opportunities and challenges.

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• Application of differential geometry in the theory of PDE
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