RTLS based Intelligent Transport System for BRTS using RFID & IEEE 802.15.4 modeled Wireless Mesh Networking

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Abstract

A wide variety of ITS technologies can be integrated with BRT system to improve its system performance in terms of travel times, reliability, convenience, operational efficiency, safety and security.

The objective of our work is primarily to investigate computer mediated communication system using rapidly deployable Active RFID based wireless communication technology, to realize a prototype of an Intelligent Transport System for BRT systems. In this paper, we review traditional Automatic Vehicle Location technologies being used to deploy ITS in BRT systems and introduce the concept of Real Time Locating Systems based on technology of Radio Frequency Identification and IEEE 802.15.4 wireless communication standard. We, hence propose design of a new system model for Intelligent Transport System based on Real Time Locating System.

Keywords: RTLS, IEEE 802.15.4, BRTS, Active RFID.

1. Introduction

Transit agencies and implementers are considering new and innovative approaches to address the increasingly costly issues of urban congestion and the associated pollution problems while providing efficient and effective surface transportation options.

One innovative approach is the use of buses in lieu of light and/or heavy rail, in an integrated, well-defined system with design features similar to light rail systems. Bus Rapid Transit (BRT) applies the concept of Intelligent Transportation Systems (ITS) and integrated land use and planning with existing bus technologies, in order to provide significantly faster operating speeds, greater service reliability, and increased rider convenience, matching the quality of rail transit when implemented in appropriate settings. The transit industry has developed significant interest in BRT.

A BRT system is designed to address the sources of delay in traditional bus service. It is an incrementally enhanced transit mode, effectively providing a faster, more efficient and more passenger-friendly quality of service. This can be accomplished in multiple ways that include improvements in the infrastructure, vehicle road use, advanced stops/stations quieter and cleaner vehicles, and integrating an amalgam of ITS technologies. System characteristics and operational configurations of a BRT system are well documented [1].

The inclusion of advanced technology in the BRT system design is discussed at length in several references [1, 2].

The objective of this research is to explore RFID technology to establish an Intelligent Transport System for BRT system supported on wireless communication and mobile technologies for communication.

The paper is organized as follows. In second section, comprehensive review of traditional technologies used to establish Automatic Vehicle Location is given, and further concept of RTLS in introduced.

Section three explains to BRT system management architecture based on RTLS. Fourth section explains implementation of components of ITS, with respect to RTLS. It proposes further advancement in system by integration of certain sensors along with Active RFID tags.

2. Review of Real Time Locating Systems

A. Introduction to Automatic Vehicle Location Techniques.

AVL system is a collection of electronic or electromechanical devices being used to acquire information about the location of fleet vehicles. In this section we review some popular AVL technique and then introduce Active RFID based wireless mesh networking, as a prospective AVL. These are

proximity systems, dead reckoning system, radio navigation technique, and GPS [9].

1. Proximity Systems (signpost systems) provide the location of vehicles by determining the relationship between the vehicle and fixed locations. The position of the vehicle is calculated by determining the last signpost passed and distance (odometer distance) traveled.
2. Dead Reckoning System relies on the vehicle's odometer inputs and fixed route to determine the location of the vehicle. While this system is inexpensive, it does not provide information when the vehicle deviates from specified route. Factors such as side winds, changes in tire pressure and road conditions can greatly affect the distance and direction measurements.
3. Global Positioning System (GPS) uses network of multiple orbiting satellites which transmit position and time information to a GPS receiver located on the vehicle. A GPS receiver calculates its position by precisely timing the signals sent by the GPS satellites high above the Earth.
4. Active RFID and IEEE 80.15.4/Zigbee modeled Wireless mesh networking Active RFID based Real Time Locating System (RTLS) and Real Time Sensing System (RTSS), consists of small deployable active RFID tags, intelligent network of routers, a central coordinator and a system software suite which enable real time location and visual environment monitoring.

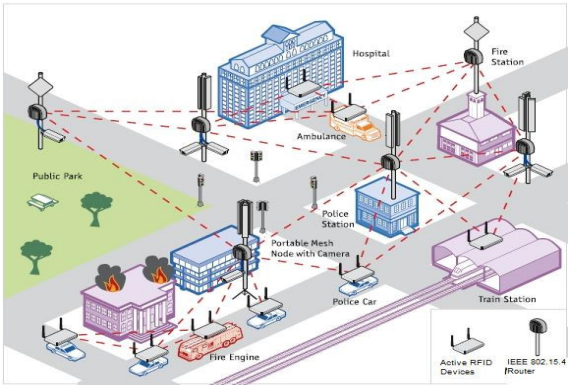

Fig .1 Structure of Wireless Mesh Network based on IEEE 802.15.4

B. Introduction to Active RFID based integrated tracking and sensing system

1) Active RFID

RFID system consists of tag, reader, and antenna. Tag which is attached to the object consists of coupling components and chips, and tag has a unique electronic coding. Reader identifies tags with location

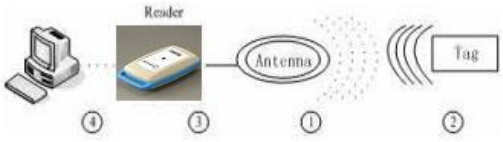

Fig .2 Work Process of RFID Technology

information without contacting and it has two types—handled and fixed reader.

The system principle is as follows: 1) reader transmits a carrier signal; 2) tags in the field of reader antenna product electromagnetic power and transmit information to readers; 3) reader receives the signal and decoding; 4) the computer receives the data and performs data processing. The work process of RFID is shown in Figure 1. [3,4,5,11].

2) IEEE 802.15.4/Zigbee based wireless communication architecture

IEEE 802.15.4/Zigbee is set of protocol specifying standards for Wireless Personal Area Networks. They provide best support for low cost, low power wireless mesh network and provides longer battery life but less data transfer rates. Main objectives of such communication system is ease of installation, reliable data transfer, short range operation, longer battery live while maintaining a simple and flexible protocol.

3. BRTS Management system based on RTLS

A. Statement of System

We propose a generic technology framework based on RFID, Wireless communication and mobile technologies for automatically locating position of buses in real time and subsequent system management. The system structure is shown in Figure 2.

Proposed framework for BRT management consists of following prime components:

1. Vehicle based RFID tag

2. Roadside RFID reader unit with GSM/GPRS connectivity (for transmission of data to server)

B. Construction of Physical Layer of System

Physical layer constitutes of installation of Active RFID based wireless network. Installation of 802.15.4/Zigbee based

communication requires strategic placement of wireless hubs or 802.15.4. Zigbee based access point equipments and does not require any complex cabling.

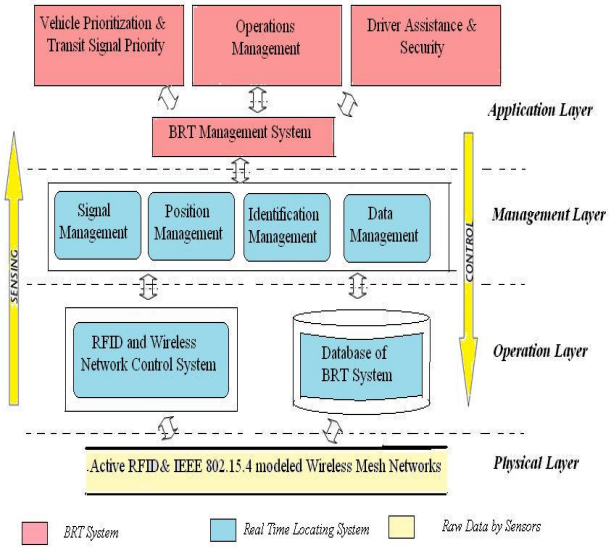

Fig .3 Schematic Representation of System Architecture of BRT management System based on Active RFID and IEEE 802.15.4 modeled Real Time Locating System

Powering on hubs or access points automatically forms wireless network for seamless coverage. Number of RF readers and reference tags can be determined on the basis of length of transit route. Accurate positions of buses and be determined by comparing relative intensity of signal, as read by installed RG tags.

C. Function Management Layer

1. Signal Management

The main function of signal management module is to control, transmit signal. It coordinates signal transmission via readers through multiple hoping avoiding non-effective signal collision and saving the system energy and resource. GSM/GPRS modules, integrated with selected tag, transmits information in form of data packets via messaging services of mobile technologies.

2. Location and Identification Management

Under this module, locations of buses are established in real time. Based on intensity of signal received by reader from tags, accurate position of buses, in between transit route is determined.

3. Data Management

The Data Management module is primarily concerned with management of data between application layer and operation layer. Data packet consist of information like current location, bus unique identification network, passenger counter's information, date and time. Combining with Signal Management module, it interacts and data transmittal between WMS and hardware with the help of wireless signal carrier.

Data flow in BRT information system is shown schematically below

<Start>

Layer 4: <Centralized Database>

Layer 3: <Coordinator's ID no> + <Reader's unique ID no> + <data Packet>

Layer 2: <Reader's unique ID no> + <data Packet>

Layer 1: <data Packet>

</stop>

Location Algorithm based on signal intensity

This system makes use of the location algorithm which is based on signal strength. If the tags are in the detection range of RF readers, the readers will record intensity of tags information. According to the relation between signal intensity and distance, reader closest to tag, detects the tag using the triangulation law. RFID system can be designed to directly read intensity of tag's signal. Reader receiving maximum intensity can receive the data packet from tag and forward it to next hop, appending its reference.

- *Triangulation/Trilateration Law:*

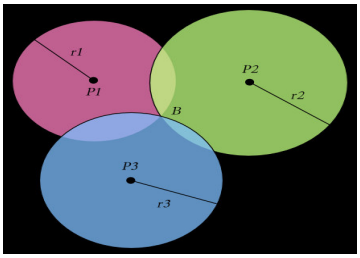

Fig .4 Trilateration Scheme

The distance between the vehicle and at least three stations is measured by determining the radio frequency travel time from the stations to the vehicle and back to the stations.

Integration with GPS and Motion sensor

GPS can be combined with Zigbee based RFID tags to provide alternate way of locating vehicles. When GPS

integrated Zigbee 2.4 GHZ tag is far away for its signal to be picked up by at least 3 802.15.4 based Zigbee access points, tag's built in GPS receiver enable to determine its longitude and latitude measurement by satellite and then transmit data via wireless transmission.

4. Implementation of Core Components of ITS

Transit Signal Priority

TSP is optimization of traffic signal along a corridor to make better use of available green time capacity by favoring BRT flows. Such kind of priority signaling solves erratic traffic congestion and improves travel time and schedule adherence. BRT buses reaching traffic intersection are given priority in crossing intersection. Priority can be given to buses running late from their schedule or between to buses, to one having larger no of passenger.

Passenger Information

Transit rider ship and traveler access to transit information are positively associated. It reduces wait times, and improves passenger satisfaction. Real time reporting of bus status and incident reporting adds dynamism to information channel.

Operation Management

1. Automatic Scheduling and Dispatch System

This module utilizes real-time vehicle data manage all BRT vehicles in the system. Automatic Scheduling and dispatching software package, based on real time location of buses, dispatches schedules accordingly, to cater system delays.

2. Maintenance Management

Maintenance is always a consideration in any vehicle or engine usage situation. Engine sensors, primarily includes *oil pressure sensor, exhaust gas sensor, engine temperature sensor, battery voltage sensor, vehicle speed sensor, odometer sensor, fuel level sensor, oxygen sensor, throttle position sensor and engine rpm sensor, oil pressure, gas sensors*.

5. Further Improvement

Largest area for improvement is ability of ITS to pick up signals from other vehicles. Data passed from buses to ITS consists of Unique Vehicle Identification number. If, for example, a government assigns the number 001 to 100 to buses and the number 101 to 200 to emergency vehicles, ITS can give emergency vehicle priority at any intersection. Drivers of such vehicles could merely turn the transmitter off when they do not require priority. ITS, thus, providing automated management of BRT system, can also speed up the response time of emergency vehicles.

6. Conclusions

With the actual characteristics of BRT system, this paper proposes a prototype for an Intelligent Transport System based on rapidly deployable Active RFID tag and IEEE 802.15.4 based wireless communication.

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