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Automatic Vehicle Location and Monitoring System Based on Data Distribution Service

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Abstract

This paper proposes a real time Automatic Vehicle Location (AVL) and Monitoring system for pilgrims road transport coming towards city of Makkah in Saudi Arabia based on Data Distribution Service (DDS). This service is a real time publish/subscribe middleware. Using this middleware approach, we are able to locate and track a huge number of mobile vehicles and identify pilgrims for an annual Islamic gathering in the Holy City of Makkah. Performance results are demonstrated for LAN, WLAN and Bluetooth over DDS.

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Keywords: AVL; DDS; Middleware; Location Tracking

1. Introduction

Applications of distributed mobile networks exist in our daily life in variety of systems such as transportation systems, healthcare systems, weather and environment monitoring systems. These systems require their mobile nodes to communicate and share data among people, vehicles [1, 2] or robots [3, 4] in real time. With the advancement of embedded systems, it is possible to allow thousands of mobile nodes to communicate and share huge amount of data. It is also possible to collect the data at the sensor levels and forward it to the application level for processing and analysis in real time. These nodes need to share and coordinate their context updates for real time

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tracking and status information. These nodes can be distributed on many vehicles for sharing their information including their locations, vehicles and passengers' status. The passengers' information can be extracted using radio frequency identification (RFID) system. Such a large-scale system requires a large scalable infrastructure that supports reliable and instant context updates for sharing among the mobile nodes [5]. The publish/subscribe model is considered best for mobile distribution environment. Many researchers have attempted to develop publish/subscribe model [6-10]. However, a few of them are able to support mobile networks. The publish/subscribe model has two characteristics. First, it efficiently distributes large amount of data to a large number of users. Secondly, the publisher and the subscriber are not required to connect simultaneously in order to distribute data. In this case, both of them don't know about their existence. Now a days, industrial automation, aerospace and defence applications use Object Management Group (OMG's) [11, 12] Data Distribution Service (DDS) middleware. The work presented in this paper uses DDS middleware for our application of Automatic Vehicle Location and Monitoring system. DDS is a scalable middleware. Its architecture is decentralized and works as an asynchronous communication model. It specifies the QoS (Quality of service) policies such as reliability, data flow prioritization, data persistence and other optimizations that are used for message delivery. The unique property of DDS middleware is that its efficiency of network resources and latency that can be controlled by fine tuning of the network services (i.e. QoS policies such as latency budget, deadline, and transport priority).

2. Related Work

For large-scale mobile system, a middleware called Scalable context-Aware middleware for mobiLe EnvironmentS (SALES) is developed [13]. SALES does not take advantage of real time DDS and depends upon UDP. Two main terminologies used are: Quality of Context (QoC) and Context Data Distribution Level Agreement (CDDLA). QoC is associated with context information distributive service whereas CDDLA is quality agreement between consumer and producer imposed by the middleware. This SALES architecture lacks the functionality of fault tolerance and QoS support.

A limited research is done in the implementation of mobile distributed applications using DDS based middleware. Among few of them is [14]. The architecture of this middleware supports mobile nodes and provides reliable data delivery. It also supports handover by switching the wireless access points. The mobile nodes in this middleware execute light version of DDS whereas the fixed nodes execute full version of DDS.

A DDS based middleware called Scalable Data Distribution Layer (SDDL) [15] [16] is proposed for real time tracking of mobile nodes. This middleware connects the stationery DDS nodes in a wired network to the mobiles nodes with IP based wireless connection. Two protocols are used in this middleware namely RTPS wire protocol for communication among the stationery nodes and mobile reliable UDP protocol for communication among the mobile nodes.

3. DDS Architecture

The Data Distribution Service (DDS) specifies a communication model that is data centric publish/subscribe for

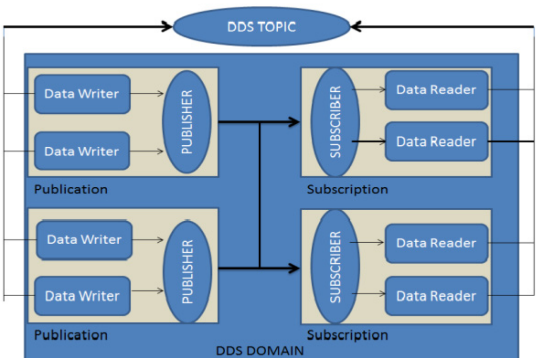

Fig 1. DDS Architecture

various computing and distributed environments. This Data Centric Publish Subscribe provides Global Data Space (GDS) where Publishers post into the GDS and the Data Centric model distributes this information to all the interested Subscribers.

A domain is virtual network area and all the publishers and subscribers can send and receive messages with in this domain. The communication between a publisher and a subscriber can take place only within a same domain that shares common interests.

A publisher is an object that according to the Publisher's QoS policies distributes data and publishes different types of data objects. Data Writers are used by the applications to write Data to the GDS.

A subscriber receives the publishing data and according to subscriber's Qos Policies, it makes this data available to the receiving application. It reads the topics from Global Data Space for which there exists a matching subscription and data readers are informed that data is received.

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4. Proposed Solution

In this section, we are proposing location and monitoring system based on DDS's RTPS protocol especially for pilgrims of Hajj (Pilgrimage) in the Kingdom of Saudi Arabia. The Kingdom of Saudi Arabia hosts thousands of Muslim Pilgrims every year from all over the world. This is the world's biggest and most important gathering in the month of zilhajj according to Islamic Calendar. Hajj is the fifth pillar of Islam and every Muslim is bound to perform this Holy Journey once in a lifetime. Hajj consists of number of rituals that are to be performed in specific locations of Holy City of Makkah. Now as the number of pilgrims is increasing each year and about 2.8 million pilgrims performed Hajj according to 2010 data. Some of these people die due to huge crowd and high temperatures. There is dire need to identify them, trace their positions and inform their families. Saudi Authorities are doing their best to tackle this huge crowd but there is a need of a system and an infrastructure which helps the authorities in management and security issues for pilgrims as well as tracking and locating them. There are many models that have been proposed to facilitate the authorities such as in [17] three security requirements are detailed and lattice model is proposed for flow of information. In [18] a bus transportation system within the Makkah is proposed and this system is tested using simulation and experiments.

For controlling and for location services for this huge crowd, each pilgrim can be provided with a GPS transmitter but implementing this solution is too expensive. Similarly another possibility is that each person can be provided with a transmitter with unique identifier and the transmitter can update pilgrim's location by sending update to the database which is integrated with GIS. Although it will be useful but signal coverage will be the main problem. Within the holy sites of Makkah, the solution of train is implemented known as Makkah Metro but till now no good solutions have been provided for pilgrims reaching this city from outside. Saudi authorities are continuously developing new solutions to manage this crowd from diverse nationalities.

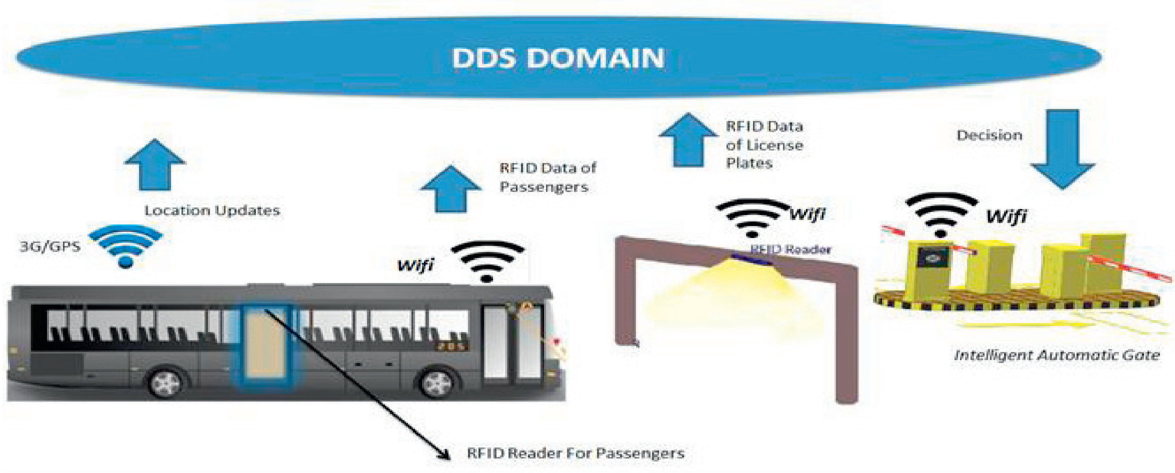


Fig 2.AVL and Monitoring System Architecture

Now with the use of embedded technology and wireless communication many issues that are faced by the authorities as well as the pilgrims can be solved. We are also considering the journey, crowd management and as well as the accidents in providing the solution.

We are proposing a huge system based on DDS standard of middleware considering about 50000 buses as mobile nodes. Our aim is to design a system for location and monitoring of both the mobile nodes as well as the passengers inside the mobile nodes. This system is especially useful for the Hajj pilgrims in Saudi Arabia for monitoring their residency status as well as permission to perform hajj. Considering different highways that are leading towards Makkah, there are checkpoints for these buses in the proposed system before entering the city of Makkah. These check points contain RFID readers, Automatic gates and the distributed server that is part of the DDS cloud. The checkpoint is about 10 km long with number of lanes. Each of these checkpoints will be able to accommodate 5000 buses or vehicles at a single instance.

4.1. Bus or Mobile node

- GPS and 3G Device: This contains GPS device for location services and updates the DDS cloud about its location through 3G services at definite interval. .
- Wi-Fi Device: Wi-Fi device is present inside the vehicle to directly communicate with the DDS cloud at the checkpoints.
- Head Counters: Over the bus thermal cameras are installed for counting of passengers inside the vehicle. This data is then conveyed to the DDS cloud via Wi-Fi.
- RFID Tags and Readers: There are multiple types of RFID Tags such as active tags, semi active tags, and passive tags.

The active tags require power source for their operation usually batteries with in the circuitry whereas the passive tags require no power source. They draw power from the electromagnetic field created by the reader. Semi passive tags draw power from the reader for communication but require batteries to run the circuitry. The active and semi active tags are expensive and are used to track the items over long range. The whole RFID system consists of a RFID Tag which consists of a printed antenna and a microchip and the RFID reader. The RFID reader sends electromagnetic waves which activates the tags. The passive kind of RFID draws the power from the electromagnetic field created by the readers. These tags then send back the waves which are converted to digital data by the RFID readers

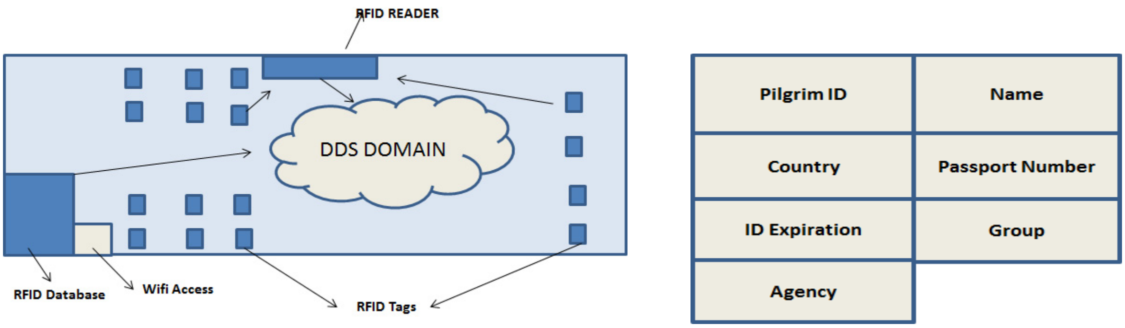


Fig 3. (a) Inside mobile node communication; (b) Message Format

RFID Readers are installed at the door of the bus. Passengers have RFID wrist bands containing smart chips. When a passenger passes through door, RFID wrist bands are scanned by the readers and all the identity data of that passenger, status of passenger(such as permission to travel) as well as the count data is stored with in a small local data base inside the bus.

There is also a need to discuss the Data Base Architecture for the passenger RFID data. The message format for RFID passenger data as shown in Fig 3(b) should include all the data such as Passenger ID, Name, Country, Permission status, Passport etc. Inside the bus the communication between The RFID local data base and the RFID reader can be wired or through Bluetooth. We will provide latency information for both these mediums in our experimental section.

4.2. The Checkpoint

The checkpoints are distributed at different entry points of the city. Each checkpoint is about 10 km long with various parallel lanes. Each checkpoint has distributed servers and data bases which are part of the DDS cloud. Also multiple RFID readers are installed for vehicle's identification. RFID tags are imbedded in the vehicle for vehicle identification. Passive tags are used and these tags draw power from the reader's field. These tags then send the vehicle's information to the readers and the readers convert this data to the digital format. . At the end of each check point there is an automatic gate that will only open after a positive decision is made inside the cloud for a particular vehicle.

4.3. The Automatic Gate:

The Automatic gate is directly connected to the DDS cloud and will open after the positive decision is made inside the DDS cloud based on different factors such as Vehicle Identification, passenger counting through thermal cameras as well as passenger Identification and status through RFID data. Now when a bus arrives at a check point it has to pass through multiple stages.

In first part of this checkpoint there are RFID readers for the verification and authentication of license plates and these RFID readers are then directly connected to the DDS cloud. In this part, a decision is made in this cloud whether this bus is allowed or not and at this stage, to verify whether this mobile node is physically present at the checkpoint or not, its location update is cross-checked with the RFID data for license plate.

In second part the stored RFID data of passenger identification and status inside the bus is passed to the cloud via Wi-Fi for authentication and decision making. If a certain mobile node (bus) has more than X% of the unauthorized passengers then the whole bus is rejected. If this mobile node has less than X% of unauthorized passengers than manual checking is done.

In third stage the thermal cameras installed on the bus will do the head counting and will convey this data to the DDS cloud via Wi-Fi. At this point the passenger count data from RFID readers and the thermal cameras is cross checked for further verification in case there are multiple readings for RFID data.

At the end when a mobile node reaches the Automatic gate, a decision is made based on the data provided to the cloud at the previous stages of the checkpoints. Such as when the decision is positive for license plate authentication at first stage, decision is positive for passenger authentication and permission at the second stage and the decision is positive after verification of the number of passengers through thermal scanners then only the Automatic gate is opened for a particular mobile node.

In our case the number of publishers is in thousands whereas subscriber is one. There are four topics for which publishers are publishing. Location update, Vehicle's data through RFID, Thermal Scanners counting data and RFID passenger's data.

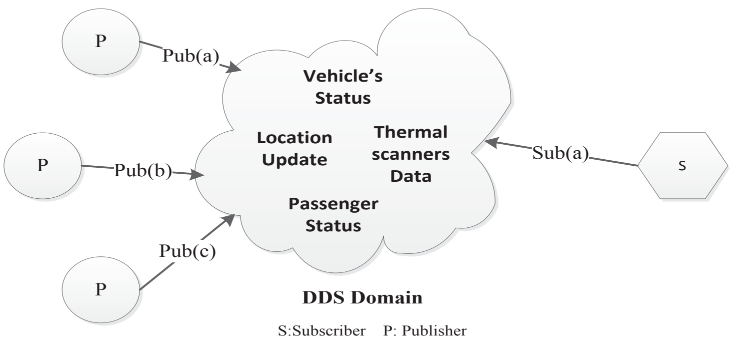


Fig 4. DDS Domain

5. Experimental work

In the first section, we evaluated and measured the performance of DDS middleware over Bluetooth wireless network for inside mobile node communication between local database and readers. The details of our experiments are explained below.

5.1. Experimental work setup for Bluetooth.

In the first step we established a WPAN over Bluetooth between two hosts A and B. Then we used host A as a publisher and Host B as a subscriber. After network establishment we ran CONNEXT-RTI-DDS Latency test to measure the packet transmission time from Host A (Publisher) to Host B (Subscriber).The latency is calculated by dividing the Round Trip Time by 2 as Latency= RTT/2.

5.2. Results and Analysis for Bluetooth

This part contains our experiments' results. The time needed for each experiment ranges from 1 hour for 1 subscriber up to 3 hours in case of 8 subscribers. Tables 1 and 2 show latency result in case of (1 and 8) subscribers respectively. The average latency is proportional to the number of subscribers and this makes sense because when the number of subscribers increase, the network traffic increases and subsequently the packet latency increases.

Table 1.Latency result 1-Publisher, 1-Subscriber

Packet Size (Byte)	AVG (m Sec)	MIN (m Sec)	MAX (m Sec)
16	12.1805	6.9619	315.8557
32	13.1721	6.9418	125.1016
64	12.453	7.6049	100.0857
128	12.7102	7.948	118.0507
1024	26.757	19.7587	141.991
2048	41	33.7635	133.9583
4096	72.33	58.835	177.9639
8192	125.87	97.8917	533.027

Table 2.Latency result 1-Publisher, 8-Subscribers

Packet Size (Byte)	AVG (m Sec)	MIN (m Sec)	MAX (m Sec)
16	34.301	24.858	177.157
32	33.896	24.793	142.512
64	34.125	24.89	162.345
128	35.529	25.468	157.275
1024	81.644	60.885	283.518
2048	128.085	97.065	459.702
4096	226.153	199.677	712.287
8192	418.848	352.365	1278.286

We also collected latency results for LAN and compared the latency for both Bluetooth and LAN as shown in the following figure.

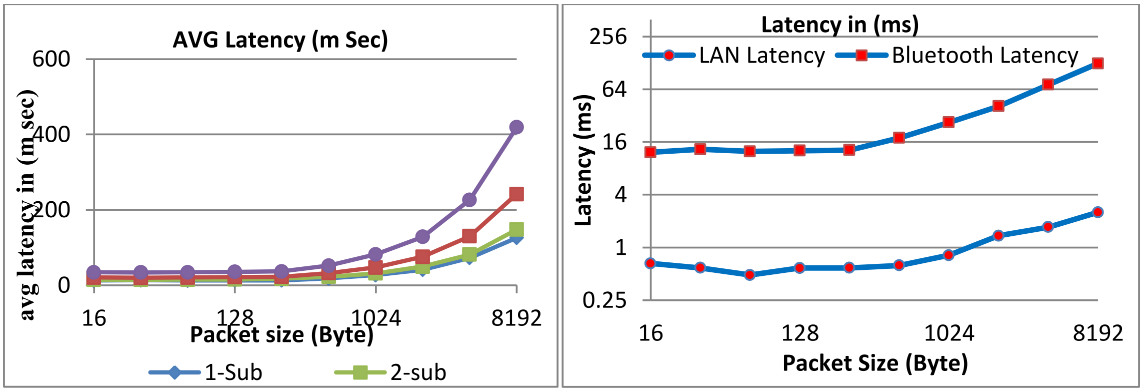


Fig 5. (a) Average Latency for Bluetooth inside mobile node; (b) Average Latency for wired and wireless inside the mobile node

In the next section, we evaluated and measured the performance of DDS middleware over Wi-Fi (Wireless LAN) for mobile node to communicate with the DDS domain. The details of our experiments are explained below.

5.3. Experimental work setup for WLAN

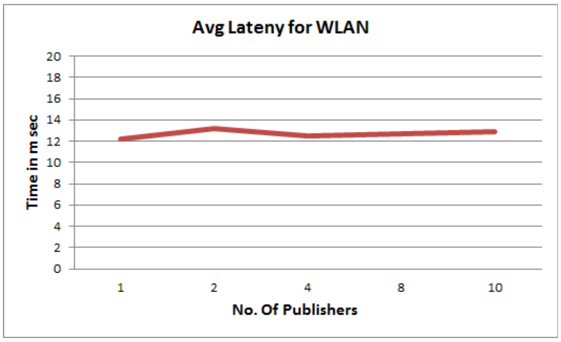
In this step up first we established a WLAN connection between two hosts A and B. Then we used host A as a publisher and Host B as a subscriber. After network establishment we ran CONNEXT-RTI-DDS Latency test to measure the packet transmission time from Host A (Publisher) to Host B (Subscriber). Similarly we increased the publishers up to 10 at a time with single subscriber and calculated the latency.

Table 3. WLAN latency for 10 Publishers, 1 Subscriber

No. of Pub	No. Of Subs	Max Delay (mSec)	Min Delay (mSec)	Std Dev (mSec)	Avg Delay (mSec)
1	1	315.8557	6.9619	257	12.180
2	1	125.1016	6.9418	275.4	13.172
4	1	100.0857	7.6049	202.8	12.453
8	1	118.0507	7.948	188.4	12.710
10	1	64.8505	9.6841	176.5	12.938

Table 4. WLAN Throughput for 10 Publishers, 1 Subscriber

No. of Pub	No. of Subs	Max Throughput (KBps)	Min Throughput (KBps)	Std Dev (KBps)	Average Throughput (KBps)
1	1	112.634	97.864	0.12311	105.351
2	1	211.210	190.725	2.3019	199.866
4	1	438.193	370.437	18.2456	423.261
8	1	465.295	403.109	16.1864	439.465
10	1	375.870	304.099	27.0273	364.295



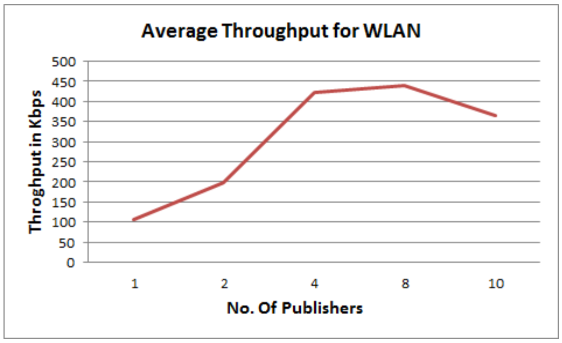


Fig 6.(a)Average Latency for WLAN communication with DDS Domain; (b)Average Throughput for WLAN Communication with DDS Domain

5.4. Results and Analysis for WLAN

From the Latency graph we can see that as the numbers of publishers are increasing there is little increase in the delay. In other words in our application for almost 5000 publishers at a same time at same place, the delay will not increase and the latency will be stable for huge number of publishers. For throughput graph we can see that throughput becomes stable after 8 publishers. So we can predict that by further increasing the number of publishers our throughput will remain stable.

6. Conclusion

In this paper, we introduced the approach with different communication mediums to solve the problem of Hajj by using OMG's DDS middleware as this task remains a tough challenge for Saudi Authorities for very long time. We discussed pilgrims' difficulties and transport congestion problems faced during the Hajj period. We proposed an automated solution based on Real-time Publish-Subscribe middleware for real time tracking and monitoring of vehicles as well as pilgrims. DDS is used as middleware because of its Data Centric and Asynchronous communication model along with rich set of QoS policies. We performed experiments for LAN, WLAN and Bluetooth and got encouraging results that can support thousands of mobile nodes at single instance. For communication inside the vehicle, LAN is suitable due to low latency and low rate for packet drop. WLAN is suitable due to its flexibility as well as scalability for mobile node to communicate with DDS domain as explained in section 5.4.

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