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Volume 2, Issue 2

Reducing delay and jitter for real-time control communication in Ethernet

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***Abstract*—The aim of this paper is to develop an approach for cheap and deterministic control communication using Ethernet. A half-duplex Ethernet network populated with a small/medium number of Media Access Controllers (MACs) is used for timed real-time communication. Data packages are sent at well defined times to avoid collisions. Collisions mainly occur due to jitter of the transmitter system, so that arbitration (similar to CANopen) is necessary. In this paper, simulation models using a Binary Exponential Backoff (BEB) scheme and a Linear Backoff scheme are developed. This paper analyzes and investigates how the backoff time affects the performance of the Carrier Sense Multiple Access protocol with Collision Detection (CSMA/CD) in a basic Media Access Controller (MAC), in terms of data arrival characteristics, i.e jitter and delay. We propose to assign different minimal back-off times for each of the CSMA/CD controller units to minimize packet collisions. Simulated tests show the advantage of our approach over a standard CSMA/CD setting.**

***Index Terms*—CSMA/CD, Ethernet, Binary Exponential Backoff, Linear Backoff, network model**

I. INTRODUCTION

Research in networking technology and control engineering are blending uniquely into a challenging area, the development of embedded networked real-time applications. Hence, the applications should timely deliver synchronized data-sets, minimize latency in their response and meet their performance target.

Today, an embedded communication network offers flexibility of the designed system and reduces wiring complexity which leads to use embedded networks for safety critical applications [1], [2]. Most of the applications like robotics, manufacturing, medical, military, and transportation systems, depend on embedded computer systems that interact with the real world [3], [4]. The many fields of applications come with different requirements on such embedded systems [5], [6]. Messages in distributed embedded systems can be sent at a certain time or when an event occurs, known as time-triggered and event-triggered communications.

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Ethernet has been the predominant networking technology for over 20 years. Ethernet is potentially the most practical network solution due to its expendability, robustness and self-configuration capability. It is nonproprietary in contrast to other real-time communication protocols. These are the keys that make it widely used commercially. Our interest is to use Ethernet for real-time control communication. The required key characteristic is deterministic processing in the system [7]. Real-time control networks must provide a guarantee of service and consistently operate deterministically and correctly [8], [9], [10].

Over the last few years, various protocols have been proposed based on a deterministic communication scheme. A number of network architectures solve the communication problems: protocols such as EtherCAT, ControlNet, Interbus, Time Triggered Ethernet (TTEthernet), CANopen, and CAN have been developed specifically for networking embedded real-time systems [11], [12]. EtherCat (Ethernet for Control Automation Technology) is an open real-time Ethernet network, based on standard Ethernet. EtherCat communication employs a master and slave approach where dedicated hardware is used for slave implementation. A frame is composed and periodically sent by the master and transferred to all slave units and finally sent back to the master. TTEthernet combines standard Ethernet network traffic and hard real-time communication for the same infrastructure. It integrates time-triggered and event triggered traffic into a single hardware infrastructure for distributed communication with mixed critical time requirements. TTEthernet relies on specific switches to organize the data communication and establish global synchronization. Custom switches to support the time triggered communication model are only available from TTTech [13].

Basic ideas of our work are lent from CAN. CAN is a deterministic network which is protocol optimized for short messages. The messages have different priority, and higher priority messages always gain access to the network [14], [15], [16]. Therefore, the transmission delay for higher priority messages can be guaranteed. But, compared with the other networks, CAN has a slow data rate of a maximum of 1Mb/s. Variants of CAN, Profibus and CANopen, for example, use a master-slave architecture in which one node controls all communication on the network which carries certain benefits and cost. A CANopen network uses, a synchronization signal,

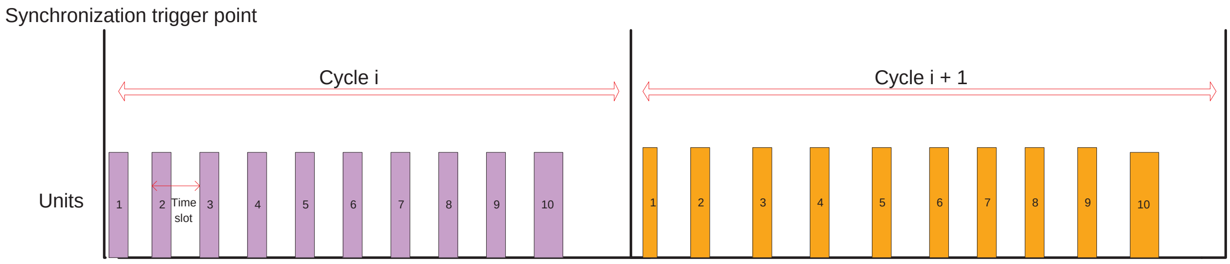

Fig. 1. *Time slot for the communication network approach*

the 'transmit signal', which triggers transmission of different nodes at the same time. The data frames need to be arbitrated. In CAN-networking, prioritisation via the CAN-address is used. As a result, the time-triggered architecture (TTA) offers fault-tolerant and deterministic communication services. For Ethernet, many modifications of CSMA/CD have been extensively studied considering software and hardware based solutions to enhance the operating system and application layer [17], [18], [19], [20], [21], [22], [23].

This paper aims to establish a cheap control solution for communication and deterministic real-time communication in Ethernet using CANopen similar network features. Thus, a synchronized signal causes the sending of short data packages from CSMA/CD controllers, which have a data package scheduled. The main feature of this strategy is that a specific minimal backoff time and a specific slot time for each CSMA/CD controller unit is used for minimal packet collisions. In particular, the assignment of different minimal backoff times to each CSMA/CD controller results in reduction of collisions, as it will be seen later. Thus, this paper uses the existing CSMA/CD protocol and investigates how the back-off interval affects the performance in a LAN (Local Area Network). We explore the benefits of the original CSMA/CD scheme for better performance without significant modification.

The rest of the paper is organized as follows. In Sections 2 and 3, the principles of the communication system and the simulation setup are described. Section 4 describes the simulation setup and Section 5 analyzes the CSMA/CD performance under different minimal back-off interval scenarios. Finally, Section 6 concludes this paper.

II. COMMUNICATION IN ETHERNET NETWORKS

This section revises the media access control (MAC) protocol, based on Carrier Sense Multiple Access/Collision Detection (CSMA/CD) and introduces important network characteristics.

A. *Ethernet and CSMA/CD*

The Binary Exponential Backoff (BEB) algorithm is used [24]. At a time, when a station wants to transmit, it listens to the transmission medium. When a node detects a carrier, its Carrier Sense is turned on and it will defer transmission until the medium is free: if two or more stations simultaneously begin to transmit, a collision occurs. In this case, the BEB algorithm for a random time interval is employed as below:

- When a collision occurs, each CSMA/CD unit chooses to back off for a period of time, determined by the backoff value. The maximal backoff time value at each unit involved in the collision is multiplied by 2 (maximum upper bound of 1024 for the factor). The first or initial backoff time value is termed *'the minimal backoff time'*. Each CSMA/CD unit will choose a random backoff time value which follows an equal distribution with an upper bound given by the maximal backoff value.
- On a successful transmission, the transmitting unit sets its backoff value to zero.
- If a unit has attempted backoff 16 times due to collisions for transmitting the same packet, the BEB algorithm forces that unit to discard that packet. Furthermore, the backoff value of this unit is reset to zero, i.e any new backoff/retransmission attempt will be determined again by the minimal backoff time.

B. *Jitter*

Jitter is one of the critical parameters in high speed data communication channels [25]. In real-time technology, a missed hard deadline can have serious consequences. All real-time systems have a certain level of jitter (a variance on actual timing). In a real-time systems, particulary, jitter should be minimal so system performance can be guaranteed. In high speed communication systems, jitter will generally degrade performance. Jitter is used to express how much individual latencies tend to differ from the mean.

The standard deviation which is related to the message transfer jitter is given by Equation (1), where N is the total number of simulated packets, x_i is the delay of each transferred packet and $\bar{x}$ is the evaluated average packet delay.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \quad (1)$$

In our analysis, we use the standard deviation to measure the jitter.

III. PRINCIPLE OF OUR COMMUNICATION NETWORK APPROACH

We have four principles for the suggested real-time communication. The first principle is the synchronization signal, the second is the introduction of a time slot for each

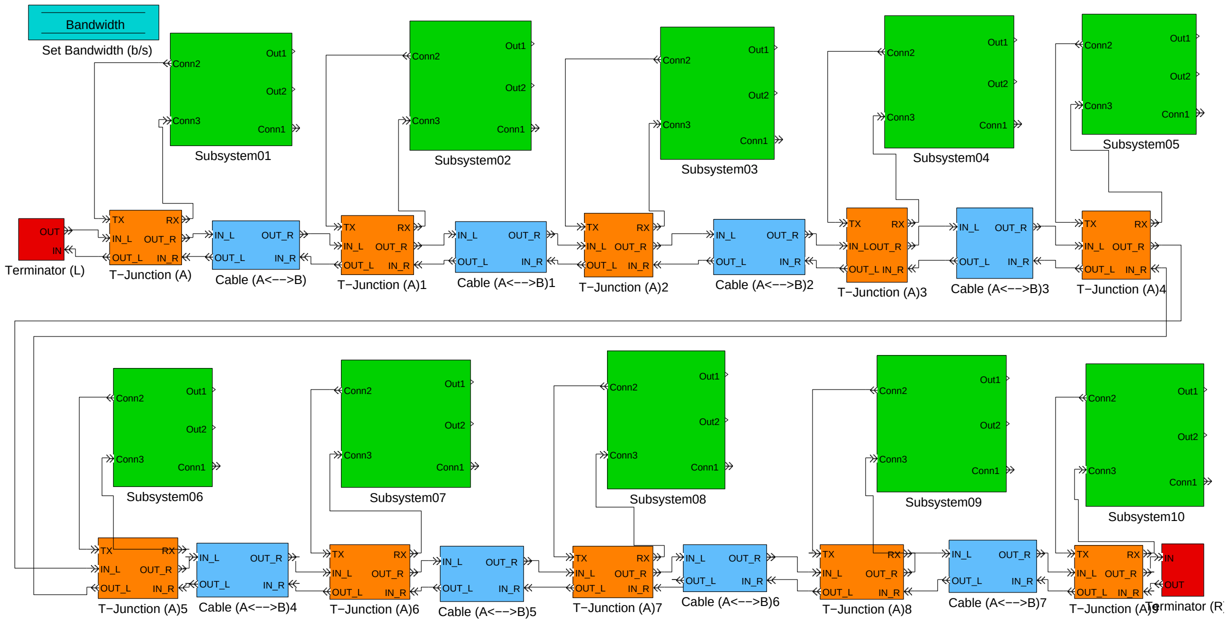

Fig. 2. *Network simulation model [26]*

Ethernet package and finally the application of different minimal backoff times for each MAC. In this paper, the length of one data package is fixed to 64 bytes for a 100Mbps network. Fixed-length and fixed-order transmission has a predictable transmission time and reduce the probability of frame collision.

- **Synchronization signal:** Real-time applications require tight synchronization so that the delivery of control messages can be guaranteed within defined message cycle times. In this paper, we have employed an internal synchronization clock for each CSMA/CD/MAC unit. It implies a precise clock synchronization among the different units so that all nodes are able to agree on their respective transmission slot. Practical implementation would be possible by using the IEEE 1588 clock synchronization approach.
- **Dedicated time slot for each of Ethernet unit:** In this communication network approach, we specify a time slot for each unit to avoid initial collision in the network bus. Messages are sent at time slots assigned to each of the units. Figure 1 shows the communication network approach.
- **Applying different minimal backoff times:** Despite data are sent at well defined time slots, jitter of each CSMA/CD unit may cause that data packages are sent outside their time slot and collisions occur. The BEB scheme comes into play for the half duplex Ethernet network. For, this the minimal backoff is specifically assigned to each of the CSMA/CD units.
- **Linear Backoff Scheme:** In a Linear Backoff scheme, the increase of the maximum backoff window grows linearly on each successive failure.

IV. SIMULATION SETUP

Simevents, part of Simulink for Matlab is used for modeling the communication bus. It uses state flow chart for implementation of the backoff logic in the communication system. The system consists of 10 CSMA/CD/MAC units that share the bandwidth on the Ethernet bus. The physical components of the network are represented by the terminator, T-junction, and cable blocks at the bottom of the simulation model. Apart from that, this model provides the number of collision and delivered packets of each unit [26].

This simulation system enables to evaluate characteristics such as the average latency and jitter of the message transmission. Each of the units consists of the following:

- An Application block that models the consumption of data.

- A MAC controller that governs the Ethernet unit's use of the shared channel.
- A T-junction to connect each of the units to the network model.

This basic setup [26] allows the implementation of our specific problem for synchronized sending of data packages.

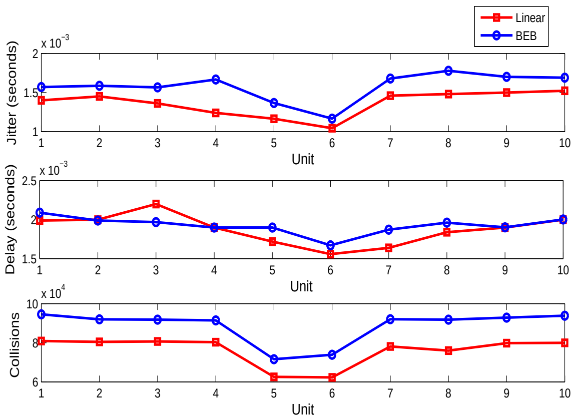

Fig. 3. *Jitter, delay and collisions for Case 1*

TABLE I
CASE 1 : IDENTICAL MINIMAL BACKOFF TIME AND IDENTICAL SENDING TIME.

Scheme	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	1.4068ms	1.8393ms	94,689
Linear Backoff	1.3063ms	1.6881ms	80,715

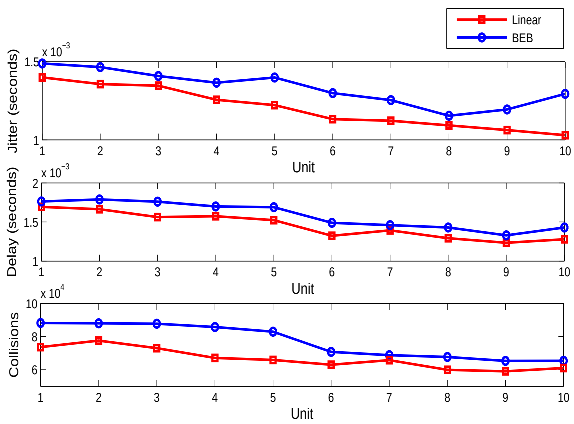

Fig. 4. *Jitter, delay and collisions for Case 2*

For this, we specify the packet generation rate and packet size range at the application blocks, the transmission buffer size of 25 packets at the MAC Controller blocks, and the length of the cable at the Cable blocks. We also implemented additional Simulink logic to measure the latency of the communication network from a transmit point, Tx to receive point

TABLE II
CASE 2 : DIFFERENT SLOT TIME AND IDENTICAL BACKOFF TIME.

Scheme	Slot Time	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	(ST1)	1.2761ms	1.6745ms	88,194
Linear Backoff	(ST1)	1.1847ms	1.4913ms	74,670
Binary Exponential Backoff	(ST2)	1.1825ms	1.6211ms	87,637
Linear Backoff	(ST2)	1.1750ms	1.4522ms	72,491

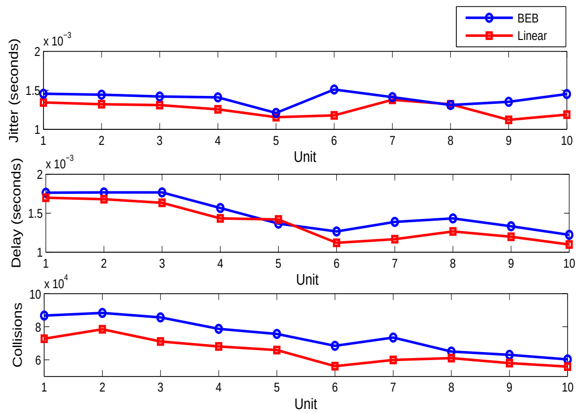

Fig. 5. *Jitter, delay and collisions for Case 3*

for, Rx in the Ethernet MAC control block to measure the sending of a packet. All the units transmit at the average rate of 100 packets per second with the packet size of 64 bytes and the length of the cable determined at the Cable blocks of 100 meter. The synchronization signal has a frequency of 100Hz which is artificially created by a synchronized signal through a frequency generator in the subsystem application block.

It is assumed that the data source has a certain jitter: each packet is created with a jitter of 10μs (standard deviation). The packet rate guarantees that any collision between packets is only due to packets being sent after a synchronization event. Thus, no collision should occur due to overload of the network, but only arbitration between synchronized data packets. This guarantees to understand the true delay and jitter due to our suggested scheme. The statistical evaluation of jitter and packet delay is carried out for 300 seconds. This gives a sufficiently large number of synchronization events for statistical evaluation.

V. SIMULATION ANALYSIS

The performance of the proposed strategy is compared to the traditional setting of the backoff scheme in Ethernet. It is our target to investigate the effect of different minimal backoff intervals and dedicated sending time slots for each MAC unit. The approach is to assign the minimal back-off times and sending time slots either in a random fashion or

TABLE III
CASE 3 : DIFFERENT MINIMAL BACKOFF TIMES AND IDENTICAL PACKAGE SENDING IN TIME SLOTS.

Scheme	Backoff Time	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	(BT1)	1.2187ms	1.5766ms	85,698
Linear Backoff	(BT2)	1.1531ms	1.4563ms	75,945
Binary Exponential Backoff	(BT2)	1.1471ms	1.3271ms	81,760
Linear Backoff	(BT2)	1.1092ms	1.2116ms	72,512

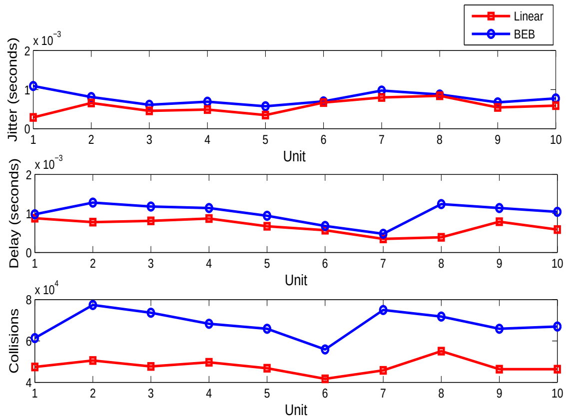

Fig. 6. *Jitter, delay and collisions for Case 4*

according to a linear approach to the 10 available MACs.

Case 1: Identical minimal backoff time and identical sending time.

For this case, all the data packages are sent with identical minimal backoff time of 51.2 μs and an identical sending time triggered by the synchronization signal, is set for each CSMA/CD controller unit. Table 1 summarizes the performance of both schemes and Figure 3 and Table 1 illustrate the values of jitter, delay and number of collisions for each MAC unit controller. As illustrated, the results show for this case that the Linear Backoff setting is the better strategy to reduce jitter, delay and collisions. Clearly, the Linear backoff scheme appears to be more deterministic than the BEB scheme as jitter in general about is 9.2% smaller.

Case 2: Identical minimal backoff times and different package sending in time slots.

We investigated the backoff characteristic by assigning different time slots for the sending of each data package (see Table 5, ST1 and ST2). The minimal backoff times for each MAC unit is identical at the value of 51.2 μs for both the BEB and Linear Backoff scheme. The assignment of different sending slots to data packages will reduce the need for arbitration, although collisions are still expected due to jitter in the transmission units/times. Again, based on Table 2 and Figure 4, the Linear Backoff scheme shows an advantage over the BEB scheme. Nevertheless, a general decrease in jitter is also evident from Case 2 in relation to Case 1. This is clearly due to the different time slots for each MAC-unit. However, note that for the ST1 scheme, some MAC-unit use similar slot times in this case. This contrasts scheme ST2, where each MAC unit has different time slots. Thus, less arbitration, collisions and lower sending jitter, delay are observed for ST2 in relation to ST1.

TABLE IV
CASE 4 : RESULTS OF DIFFERENT MINIMAL BACKOFF TIMES AND DIFFERENT SLOT TIMES.

Scheme	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	0.9760ms	1.0819ms	71,392
Linear Backoff	0.7642ms	1.0431ms	54,885

Case 3: Different minimal backoff times and identical package sending in time slots.

We observed the backoff characteristic by assigning different minimal backoff times (as in Table 5 (BT1)), multiples of 51.2μs, to each of the MAC controller in the Ethernet network with identical package sending time slots. Table 3 and Figure 5 depict the network performance for both schemes where the random different backoff times still affect the results of jitter and delay in comparison to Case 2. In this case, the Linear Backoff scheme has again achieved a better level of performance over the BEB scheme. It is interesting to note that there is an advantage of the Linear Backoff scheme in Case 3 over Case 2 results. Thus, the backoff algorithm and the minimal backoff times have significant effect on jitter.

Case 4: Linearly increasing minimal backoff times and different package sending in time slots.

In this case, the minimal back-off times are linearly distributed across the ten MACs. The principal idea is to reduce collision between different packages once a first collision has occurred. By assigning different minimal backoff times and different slot time (see Table 5 (ST1 and BT1) to the Linear and BEB algorithms of each MAC unit, it is hoped that the MACs will have a lowered probability of collision. Hence, in this case, each unit in the network model has been specified by the different minimal backoff and slot time value as in Table 1. Figure 6 and Table 4 illustrate the performance result of the communication in Ethernet networks.

Case 5: Random minimal backoff times and package sending in time slots.

For further investigation, the minimal back-off times are randomly distributed across the ten MACs (see Table 3 (ST2 and BT2)). Table 6 and Figure 7 illustrate the performance

TABLE V
SIMULATION : DISTRIBUTED SLOT TIMES WITH RANDOM BACKOFF TIMES

Unit	Different slot time(ST1)	Different minimal backoff time(BT1)	Different slot time(ST2)	Different minimal backoff time (BT2)
1	0.0512 ms	0.0512 ms	0.2048 ms	0.1024 ms
2	0.0512 ms	0.1024 ms	0.1024 ms	0.2560 ms
3	0.0512 ms	0.1536 ms	0.0512 ms	0.0512 ms
4	0.1024 ms	0.2048 ms	0.4096 ms	0.1536 ms
5	0.1024 ms	0.2560 ms	0.2560 ms	0.4096 ms
6	0.1024 ms	0.3072 ms	0.4608 ms	0.5120 ms
7	0.2048 ms	0.3584 ms	0.3072 ms	0.2048 ms
8	0.2048 ms	0.4096 ms	0.1536 ms	0.1024 ms
9	0.2048 ms	0.4608 ms	0.3584 ms	0.3072 ms
10	0.4096 ms	0.5120 ms	0.5120 ms	0.3584 ms

of the different test for the combination of ST2 and BT2. It is evident that the Linear Backoff scheme provides an advantage over the BEB case, as the smallest average jitter is provided by the Linear Backoff scheme. Moreover, a too close set of sending and backoff times increase the chance for collisions, which is evident when comparing Case 4 with Case 5. Case 5 shows better results since each unit has now indeed a dedicated time slot (and minimal backoff time).

Comparative analysis

After simulating all the communication scenarios as above, it has been found that both numbers of successful transmissions and collisions are affected by the back-off times for both schemes, Linear and BEB. When the minimal back-off time is not long enough the number of collisions detection scheme can be very significant. The different minimal back off time and time slot method are able to avoid the stations from repetitively entering the back off state, minimizing the collision possibility. This is particularly obvious for the Case 3 in relation to Case 2.

It is shown that Linear Backoff is significantly lower than BEB in the results of jitter, delay and collisions. In Case 5, up to 54.8% of jitter and delay can be reduced using the Linear Backoff compared to the standard setting of Ethernet, BEB scheme. One of the reasons of this scenario is that linear increments give enough backoff time to enhance the network performance by reducing the number of transmission failures. The number of collisions for both schemes particularly MAC-unit 10 has indeed significantly decreased more than 55.6%. Hence, Linear Backoff introduces a higher level of fairness. Case 5 is in fact providing the best overall result for the investigated cases here. This is also true when considering the combination of sending time slots ST2 together with minimal backoff times as in BT1 (See Table 3 for ST2 and BT1 and Table 7 for results)

In future work, longer minimal backoff times will be investigated. It is expected that a long random backoff time cause ineffective channel utilization, but a short one may suffer from high collision rate. The backoff time relates directly

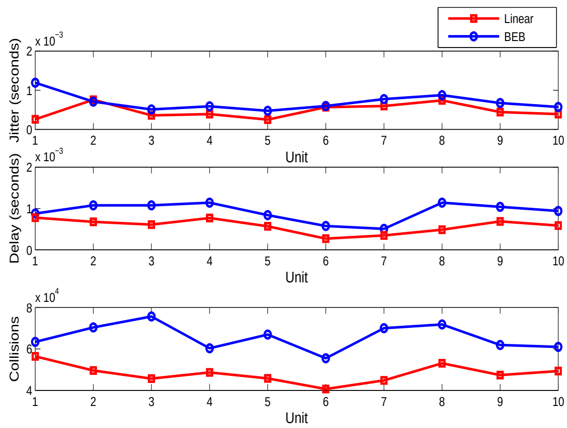

Fig. 7. *Jitter, delay and collisions for Case 5*

TABLE VI
CASE 5 : RESULTS OF RANDOM MINIMAL BACKOFF TIMES AND SLOT TIMES.

Scheme	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	0.9322ms	1.0566ms	69,795
Linear Backoff	0.7167ms	1.0163ms	52,655

to the ability to access to the channel in Ethernet network communication, lower backoff time means more chance to succeed in channel contention. Thus, it can be seen that selection of the backoff algorithm is very significant for the network performance.

Overall, the backoff mechanism dramatically affects the performance of the MAC protocol, and hence the overall network performance. The backoff period is directly related to the nodes' idle times. As a result, the standard exponential back-off scheme has been shown on 5 cases to result in high packet delays and jitter.

VI. CONCLUSION

In this paper, we constructed and simulated the original CSMA/CD protocol through Simevents-Matlab block. We

TABLE VII
RESULTS OF DIFFERENT MINIMAL BACKOFF TIMES AND DIFFERENT SLOT TIMES (BT1 & ST2)

Scheme	Average Jitter	Average Delay	Maximum Collisions
Binary Exponential Backoff	$0.9773ms$	$1.0733ms$	72,655
Linear Backoff	$0.8421ms$	$1.0345ms$	54,828

created a time synchronized bus communication by taking inspiration from CANopen, i.e packets are sent at given time slots while any collision is resolved through the BEB and Linear Backoff schemes of Ethernet in a random approach for the minimal backoff time. We analyzed the effect of the backoff time on the system performance, in terms of jitter and delay. The simulated test results have shown that the delay jitter can be reduced by choosing the correct backoff time to be implemented in the MAC controller. The special assignment of the minimal backoff times to each MAC unit allowed to minimize the packet transmission time jitter by up to 55%. The key results are that a Linear Backoff scheme exhibits lower jitter and access delay than a BEB scheme. Linear Backoff appears to be more deterministic. Our approach of an Ethernet network based communication system improves determinism at low cost.

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Design of ETC Violation Enforcement System for Non-payment Vehicle Searching

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***Abstract*—As we know, the heaviest traffic congestion on highways occurs near toll gates where vehicles make a short stop to pay the toll. So an electronic toll collection (ETC) system is usually built to eliminate the traffic jams. In order to find out the non-payment vehicles, the violation enforcement usually includes cameras to capture images of license plates, and a license plate reader system to recode photographs and license plate numbers of all vehicles. Thus, automatic license plate recognition (ALPR) technology is often used in violation enforcement. However, the identification precision of ALPR is not always reliable. Human review and correction will be needed to improve the accuracy and therefore will result in extra manual operation cost. In this paper, we consider multilane-free-flow ETC systems and formulate the non-payment vehicle searching problem into a matching problem and propose a Photograph-to-Transaction matching algorithm (PT algorithm) based on bipartite graph. The PT algorithm not only can reduce the human loading to review and correct the image recognition results but also can accurately identify all non-payment vehicles. The performance of the PT algorithm was evaluated in ns-2 simulator and three different traffic scenarios: congested traffic, normal traffic and sparse traffic. The simulation results show that our algorithm greatly reduce the number of plate recognitions, and is more feasible and reliable for ETC enforcement. This will activate some consequent activities against the violation vehicles.**

***Keyword*—ETC, multilane free flow, violation enforcement, bipartite graph, matching.**

I. INTRODUCTION

Owing to the dramatic cost down on electronic components and the advances on wireless technologies, the development of Intelligent Transportation System (ITS) has drawn intensive attention in recent years from many countries.

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The Vehicular Ad hoc Network (VANET) is a promising approach for the future ITS. In this novel architecture, the in-vehicle device (On-Board Unit, OBU) can communicate with roadside units (RSU) and with each other, referred to as vehicle-to-roadside (V2R) and vehicle-to-vehicle (V2V) communication, respectively. Due to VANETs have the characteristics of low-latency transmission and rapid topology change, 802.11 doesn't fit with above characteristics. So the Intelligent Transportation Systems (ITS) Committee of the IEEE Vehicular Technology Society (VTS) develops the IEEE 802.11p/1609.X draft and the Federal Communications Commission (FCC) of the U.S allocates 75MHZ Dedicated Short Range Communication (DSRC) spectrum within the (5.85-5.925) GHZ for VANET [19]. The overall bandwidth is divided into seven channels which are composed of one control channel (CCH) and six service channels (SCHs). The CCH is mainly used to transmit safety-critical messages and high priority messages in the form of WAVE short message. On the other hand, the SCHs are used to deliver non-safety messages.

In all applications for VANET, it can be divided into two main categories: safety and non-safety applications. The purpose of the safety application is to transmit the emergency messages and collision avoidance to decrease the traffic accident. The emergency messages are usually reserved at the specific zone for a long time so that the drivers can pay attention to the warning area. The Cooperative Collision Avoidance (CCA) [2] informs the backward vehicles the front road information so that the vehicle collision accident could be reduced. The common characteristic of the applications are that the messages should be propagated in low delay time reliably. In non-safety applications, the focus is on transmission of large data files, multi-hop communication and service provision such as the Electronic toll collection (ETC).

According to a research of traffic congestion on highways, the heaviest congestion occurs near toll gates where vehicles make a short stop to pay the toll. Hence, the primary cause of traffic jams can be eliminated by building an ETC system. Through wireless communication between OBU and the roadside antenna of a toll gate, vehicles are able to pay the toll and drive through toll gate without stopping. In general, ETC systems currently used in the world can be classified into two types: single-lane free flow (SLFF) and multilane free flow

(MLFF) as shown in Fig. 1. It is also known that MLFF ETC systems have much greater complexity than SLFF ETC systems, but the former is more convenient for faster passing due to the less restriction on vehicle speed.

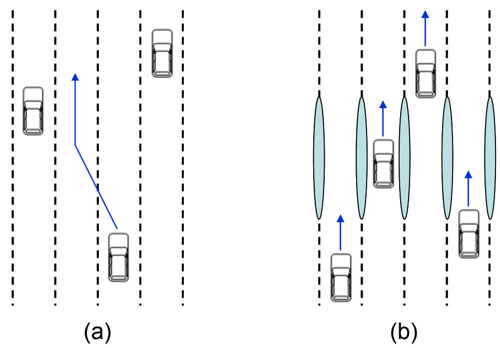

Figure 1. (a) Multilane Free Flow. (b) Single Lane Free Flow.

In Fig. 2, it shows the four components of a typical ETC system [15]. It includes 1) Automatic Vehicle Identification (AVI); 2) Automatic Vehicle Classification (AVC); 3) transaction processing; and 4) violation enforcement. The AVI component involves the use of OBU-to-RSU communications to identify the vehicle when entering the toll gate area. The type of OBU can be either a transponder or a radio-frequency identification (RFID) tag so that the vehicle can automatically be identified. The communication technology of ETC can be classified into two types of categories: Dedicated Short Range Communication (DSRC) System and Vehicle Position System (VPS). In DSRC system, it has two main communication technologies called infrared and microwave. The infrared communication technology is mature and has the features of low cost, fewer channel collision, easy installation and maintenance. But it is also easily affected by weather conditions and only suitable for SLFF. In order to increase traffic flow throughput, microwave communication is mostly adopted for MLFF in many countries now. In VPS, it combines GPS and mobile communication such that vehicles could report its real-time position to the server and the drivers could receive the bills by cell phone. Because of the high precision requirement of the vehicle position, the technique is still not matured.

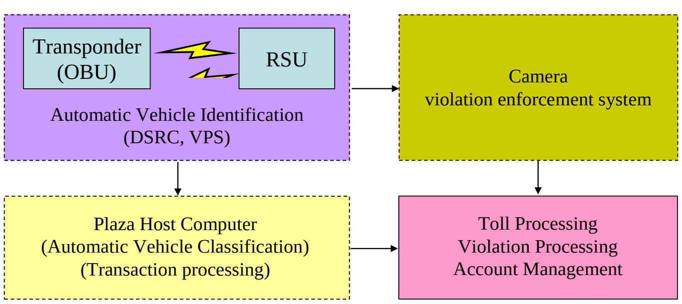

Figure 2. Electronic toll collection Architecture.

For AVC component, vehicle class can be determined by the vehicle's physical characteristics, such as the number of axles. A higher toll is usually imposed on a vehicle with more axles. Larger commercial trucks or vehicles pulling trailers, therefore, would likely pay a higher toll. Transaction processing entails debiting the toll from the customer's account and addressing customer inquiries. Violation enforcement usually includes cameras to capture images of license plates, and a license plate reader system to recode photographs and license plate numbers of all vehicles. Thus, automatic license plate recognition (ALPR) technology is often used in violation enforcement. In addition to taking and recognizing pictures, the most common current practice in violation enforcement involves determining and sending out written notices for each violation. The determining can be performed by matching the transaction data with the correct license plate number recognized by ALPR. As the factors of dirty plate surface, weather or equipment, so the identification precision of ALPR is not always reliable. For this reason, human review and correction will be needed to improve the accuracy of the license plate recognition. However, employing a lot of human labor for recognizing a large number of photographs will increase the extra manual operation cost. In SLFF, the violation enforcement system is easy to match the vehicle's transaction record to its image record correctly because the two records must take place at the same lane; however, in MLFF, it is relatively complicated to match the vehicle's transaction record to its image record because the transaction location can be anywhere in the highway toll gate area.

In this paper, we consider the violation enforcement of MLFF ETC systems and focus on improving the efficiency of finding the non-payment vehicles. As we known, ALPR technology is one of the important factors for matching the vehicle's transaction data to its license plate image data. However the precision of the ALPR is not always reliable as mentioned above. So human loading will be increase. In order to reduce the count of executing ALPR, we formulate the non-payment vehicle searching problem into a bipartite graph matching problem and propose a Photograph-to-Transaction matching algorithm (PT algorithm). PT algorithm not only can reduce the human loading to review and correct the image recognition results but also can accurately identify the vehicles that drive through a highway toll gate area without paying for toll. The rest of this paper is organized as follows: Section 2 provides previous results and system model. Based on the system model, the PT algorithm for identifying all violations is proposed in Section 3. In Section 4, we show and discuss the simulation results. Finally, our conclusions are given in Section 5.

II. PRIOR WORKS AND SYSTEM MODEL

A. Prior Works

Currently in the world, many countries and cities have conducted the MLFF system, and many related techniques have been proposed [3-13, 16-18]. Some of these researches were proposed for AVI components. In [12], the authors designed in-pavement antennas with carrier frequency 915MHZ. The tag is on the lower edge of the front license plate, and the in-pavement antennas are buried under the road. The transmission range is one meter wide and 2 meter high. It support variable bits packet for several operations. However, it is not sufficient for congested traffic. In [9] the authors proposed MLFF architecture for ETC. The gantry is 6.2m height cross the width of three lanes and the transceivers are with carrier frequency 5.8GHz. In [10] the authors proposed a novel architecture by employing millimeter-wave range in MLFF. Each lane is equipped with antennas and the frequency of each is different. The proposed scheme utilized high resolution in lateral directions to track the vehicle's direction. This is for separating the packets into segments so that can communicate with RSU consecutively. The communication range may overlap on the intersection of adjacent lane.

Some of researches were proposed for AVC components. In [16], the authors proposed a wire device that can get the electronic signal when vehicle passing. The device can classify type of vehicles by the variation signal information. ETC System can utilize the information to toll different amount of money.

For violation enforcement system, some of papers were also proposed to study the performance in MLFF. In [6], Lee et al. designed and implemented a MLFF system based on VPS techniques. As shown in Fig. 3, a virtual toll zone is a rectangle area identified by a pair of coordinates $\{(x_1,y_1), (x_2,y_2)\}$, and consists of notification area, toll area and enforcement line. The vehicle moving into the notification area will be notified that a tolling transaction is going to be carried out, and the debit transaction is going on when the vehicle passing through the toll area. Enforcement line has enforcement devices such as cameras, vehicle classification sensors installed on it in order to identify the vehicle class and capture the vehicle license plates. Camera modules take pictures for every vehicle entering the toll area and ALPR module recognizes every license plate number in order to discriminate the registered and un-registered vehicles by matching the license plate number with the tolling transaction data. Since all the missions should be done in nearly real time, it is a computing critical task for the enforcement system. The authors, therefore, propose a match pre-processing skill to reduce the computing capacity in license plate recognition and arise the pre-matching accuracy. The license plate number is sent to the enforcement system immediately by querying the registered user database in the backend system when it receives 'TS' message, an online debit message send tracks in toll zone, from a vehicle. Thus whenever the vehicle passes through the enforcement line, the enforcement system has the capability of 'prediction' the next coming registered vehicle license plate. This action improves the efficiency and accuracy of ALPR and match pre-processing. The match pre-processing is done when the license plate number received from the backend is matched to the license plate number recognition, and all the images of unrecognized vehicle is stored in the backend database for the post matching and violation processing.

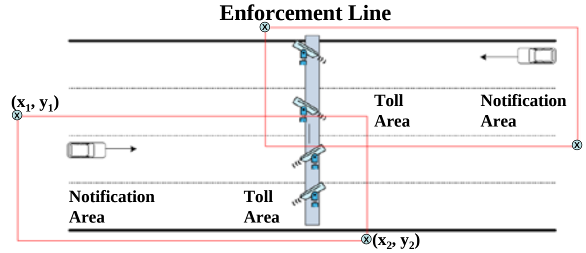

Figure 3. Virtual toll zone configuration in VPS system.

In [17], the authors proposed a tolerant algorithm to match the license plate number with the tolling transaction data. The steps of this algorithm are as follows: 1) for all license plate numbers recognized by ALPR, if there exists a transaction data which can fully match with the digits of the license plate number, the license plate image is a paid vehicle. 2) For remaining license plate numbers, if there exists a transaction data which can match with four or more digits, the license plate image also can be seen a paid vehicle. 3) Discriminate all unmatched license plate numbers to be paid or unpaid by manual operation. In [18], the authors also consider the MLFF system based on VPS and proposed an automatic matching method to improve the performance of violation enforcement. As shown in Fig. 4, the vehicle equipped with GPS receiver will report the location information per second when passing through the toll area. The lane location where the vehicle is taken a picture at can be estimated by two location points at the left and right sides closest to the enforcement line. Then the enforcement system only needs to check the image data captured by the camera located at the same lane location, and the computing capacity can be reduced.

We observe that the methods discussed in previous literatures about improving the performance in violation enforcement system still need to recognize all the image data. Human review and correction is still needed to improve the identification precision of ALPR. In contrast, our algorithm not only can reduce the human loading but also can accurately identify all non-payment vehicles.

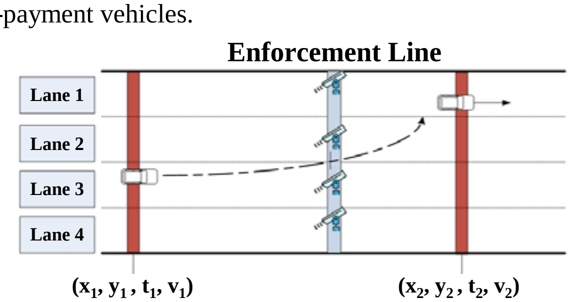

Figure 4. Two location points to estimate the lane position.

B. System Model

In this paper, we consider the MLFF ETC system and propose a PT algorithm to identify all violations. As shown in Fig. 5, the scenario of the road is a highway with 4-lanes. There is a RSU to provide the AVI service and transaction processing, and each lane is equipped with a camera at the enforcement line. For PT algorithm, the primary step is to create a bipartite graph representation of the relation between license plate image data and transaction data. The flow for creating a bipartite graph is described as follows. Consider Fig. 5. A vehicle equipped with an OBU is driving on a highway. When the vehicle enters the highway toll gate area identified by the RSU, the OBU can use wireless communication to pay the toll to the RSU and then the RSU sends the transaction data to the enforcement system. The transaction data includes the time of transaction and license plate ID information. When the vehicle passes through the gate, the enforcement line will take a picture of the license plate in order to get the license plate image data. At the same time, the enforcement system gets the speed of the vehicle and uses the time of taking the picture (T1) to infer the times of entering (T2) and exiting (T3) the toll gate area. All the transaction data from T2 to T3, said the possible matching targets, will be connected to the image data. As the shown example in Fig. 5, there are five transaction data from T2 to T3. So the image data has five possible matching targets. In Fig. 6, for each image data, we can connect it with the corresponding transaction data and then a maximum connected bipartite graph G(P∪T, E) is created, where the set of vertices P represents image data, the set of vertices T represents transaction data and the set of edges E represents links between P and T.

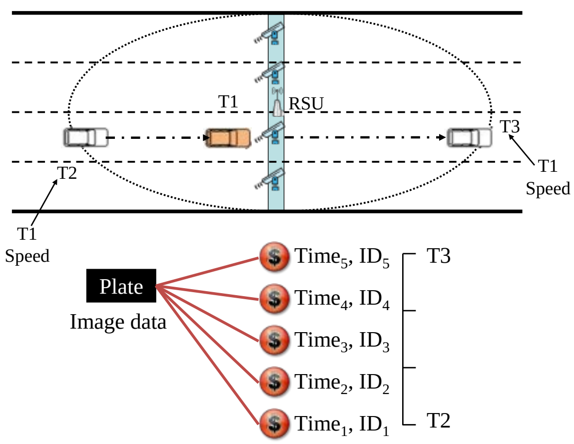

Figure 5. An image data and the possible matching targets.

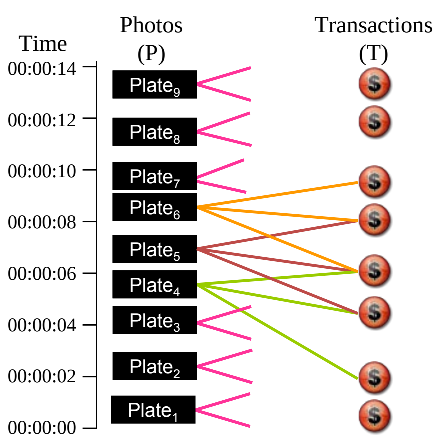

Figure 6. A bipartite graph representation of the relation between image and transaction.

III. THE PT MATCHING ALGORITHM

Throughout this paper, we focus on an undirected graph without loops and follow [14] for graph theoretical definitions and notations. Let G(V, E) be a graph and v∈V(G) be a vertex. We use the notation N(v) and E(v) to denote the set of vertices connected to v and the set of edges incident with v, respectively. The cardinality |E(v)| is called the degree of v, denoted by deg(v). Consider a maximum connected bipartite graph G(P∪T, E) representing the relation between license plate image data and transaction data. Then G(P∪T, E) has the following properties:

Property 1. The number of vertices of the image data set P must be greater or equal to the number of vertices of the transaction data set T.

1.1 If |P| = |T|, all the vertices in P are legal vehicles. The legal vehicle means that it drives through the toll gate area with paying for toll.

1.2 If |P| > |T|, there exists at least one illegal vehicle in P without paying for toll.

Property 2. For a vertex v in P, if v is a legal vehicle, the transaction data of v must be in N(v). It means that the transaction data of v is in the set of possible matching targets of v.

Property 3. For a vertex v in P, if deg(v) = 0, v must be an illegal vehicle.

Property 4. For a vertex u in T, the image data of u must be in N(u).

Property 5. For a vertex u in T, if deg(u) = 1 and vertex v is the only neighbor of u, v must be a legal vehicle and u is the transaction data of v.

Consider an example of a bipartite graph as shown in Fig. 7(a). The degree of the transaction data with the license plate ID P01802 is one and Plate$_1$ is the only neighbor. So Plate$_1$ must be a legal vehicle and the other two edges adjacent to Plate$_1$ can be ignored. Using the same method, the transaction data with the license plate ID B00010 and A21787 also have degree one. Hence we can say that plate$_2$ is mapping to B00010 and plate$_3$ is mapping to A21787. After removing irrelevant edges, the bipartite graph can be simplified as shown in Fig. 7(b).

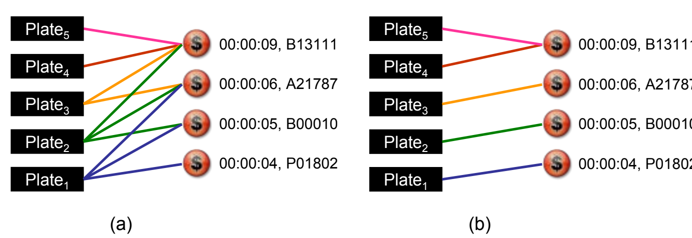

Figure 7. (a) Initial bipartite graph.
(b) Removing irrelevant edges by Property 5.

According to the properties mentioned above, a Photograph-to-Transaction matching algorithm is proposed for determining the non-payment vehicles in MLFF system. Fig. 8 shows the execution of each step of the algorithm. The main spirit of the algorithm here is the use of Property 1. When the number of vertices of the image data set is equal to the number of vertices of the transaction data set, it can determine all the image data are legal vehicles quickly and reduce the number of image recognitions. On the other hand, if the number of image data is greater to the number of the transaction data, there exists at least one illegal vehicle in image data set. In this case, the image recognition processing can make that the two sets have the same number of vertices or disconnect the bipartite graph into several disjoint components. For each component, it is recursive and used as the input of the algorithm.

```
1   Input: a maximum connected bipartite graph G(P∪T, E).
2   Output: two sets of illegal vehicles and legal vehicles.
3   Input (G(P∪T, E)) {
4     If |P| = |T|
5       move u into the set of legal vehicles, ∀u∈P;
6       exit;
7     If |P| = 1 and |T| = 0
8       move u into the set of illegal vehicles, where u∈P;
9       exit;
10    run Check_Degree_One_Vertices_In_T;
11    If G is disconnected and has G1, G2, …, Gn components
12      ∀Gi, Input(Gi(Pi∪Ti, Ei)), i = 1, 2, …, n;
13    else {
14      while (G is connected and G is not empty) {
15        take the middle node u∈P;
16        Image_Recognition(u);
17        If (License_check(u) = true)
18          move u into the set of legal vehicles;
19        else {
20          move u into the set of illegal vehicles;
21          If |P| = |T|
22            move u into the set of legal vehicles, ∀u∈P;
23            exit;
24        }
25        run Check_Degree_One_Vertices_In_T;
26      }
27      If G is not empty and has G1, G2, …, Gn components
28        ∀Gi, Input(Gi(Pi∪Ti, Ei)), i = 1, 2, …, n;
29    }
30  }
```

Figure 8. The Photograph-to-Transaction matching algorithm.

The details are described as follows.

- line 1 and 2: Explain the input and output.
- line 3: The input is a maximum connected bipartite graph G(P∪T, E)
- line 4 ~ line 6: Apply Property 1.1 to check whether the number of vertices of image data set is equal to the number of vertices of transaction data set or not. If agree, all image data are legal and moved to the set of legal vehicles.
- line 7 ~ line 9: Apply Property 3 to check whether the number of vertices of image data set is equal to one and the number of vertices of transaction data set is equal to zero. If agree, the only image data is illegal and moved to the set of illegal vehicles.
- line 10: Run the Check_Degree_One_Vertices_In_T function. By Property 5, for a vertex in transaction data set with degree one, the only neighbor of this vertex must be legal and can be moved to the set of legal vehicles.
- line 11 ~ line 12: If G is disconnected and has some components after the steps above, the components can be recursive and used as the input of the algorithm.
- line 13 ~ line 29: Use the image recognition processing repeatedly until the two sets of image data and transaction data have the same number of vertices or G is disconnected.

Now we take two examples to explain how the PT Algorithm can reduce the count of executing ALPR. Consider Fig. 9. The set of image data has nine vertices and the set of transaction data has eight vertices. By Property 1.2, there exists one illegal vehicle in P. To find the illegal vehicle, we take the middle vertex plate5 of the set P to execute ALPR first and the result is A21787. As shown in Fig. 9(a), we can find that the transaction data of plate5 is in its possible matching targets. So plate5 is a legal vehicle. Next, we remove plate5 from the set P and the transaction data with the license plate ID A21787 from the set T. After removing the two vertices, the bipartite graph is still connected and the number of vertices of the image data set is still greater than the number of vertices of the transaction data set. So we take the middle vertex plate4 of the set P to execute ALPR again and the result is B01610 as shown in Fig. 9(b). In this time, we can not find the transaction data of plate4 in its possible matching targets. So plate4 is an illegal vehicle and can be removed from the set P. Now, we can see that the two sets have same number of vertices. By Property 1.1, all the vertices in set P are legal vehicles. In this example, the system performs only twice ALPR to identify which vehicles are legal or illegal.

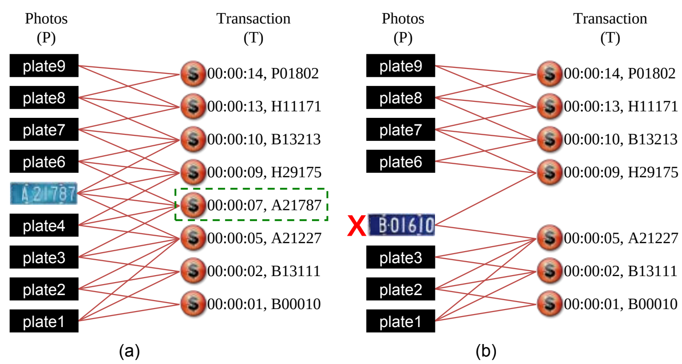

Figure 9. (a) Plate5 is recognized as legal.
(b) Plate4 is recognized as illegal.

Consider another example shown in Fig. 10. We assume that the vertex B01610 is legal. After removing B01610 from the set P and the transaction data with the license plate ID B01610 from the set T, the bipartite graph is disconnected as shown in Fig. 10(b). There are two components with four and three vertices, respectively. By Property 1.1, all the vertices in the subgraph with four vertices are legal. On the other hand, the subgraph with three vertexes exists one illegal vehicle by Property 1.2. The components can be recursive and used as the input of the algorithm to find remain illegal vehicle.

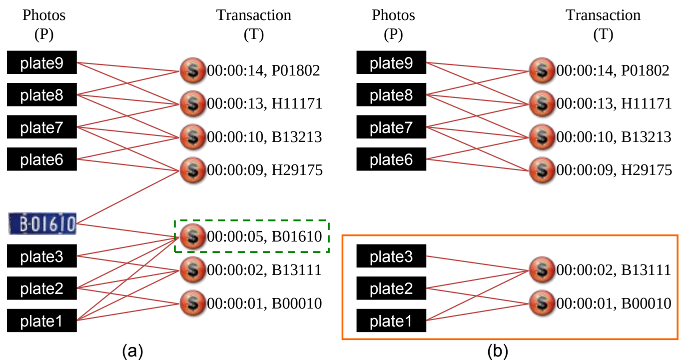

Figure 10. (a) B01610 is legal.
(b) Remain two bipartite subgraphs.

IV. SIMULATION RESULTS

A. Simplify Bipartite Graph

Before showing the simulation results, we first introduce two methods to simplify the bipartite graph in order to improve the performance of our algorithm. Since the speed of vehicles driving in the congested traffic environment is lower than the speed in the normal or sparse environment, the number of vehicles staying in the toll gate area will be increased. It means that the degree of each image data in the bipartite graph created based on the congested environment will be higher. In order to decrease the degree and simplify the bipartite graph, we assume the vehicle would report their location information when the tolling transaction is finished. According to the location information, the enforcement system can determine whether the tolling transaction is finished before the time of taking picture or not. As shown in Fig. 11, there are two types of vehicles paid road-user charges in the toll gate area. One finishes the tolling transaction at the left side of the enforcement line, and the other at the right side.

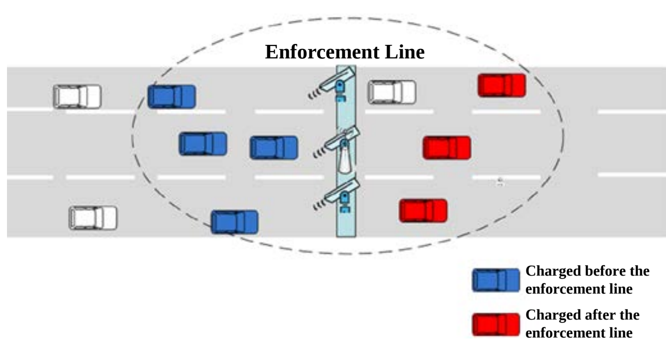

Figure 11. Two types of paid vehicles.

For the vehicles at the left side, the time of image data must occur after the time of transaction data; in the same way, the time of image data must occur before the time of transaction data at the right side. According to above characteristics, the unnecessary edges of each image data can be eliminated and further the bipartite graph will be simplified. Consider an example as shown in Fig. 12, the red vertices are the transaction data finished at the right side of the enforcement line and the blue vertex is finished at the left side. Since the transaction time of the blue vertex is 00:00:05, the time of taking the picture must be after 00:00:05, and therefore the blue vertex is only connected to plate5. Using the same method, the time of taking pictures of the red vertices transacting at the right side must be before 00:00:01 and 00:00:03, respectively. Therefore, the degree of red vertices can be decreased as shown in Fig. 12(b).

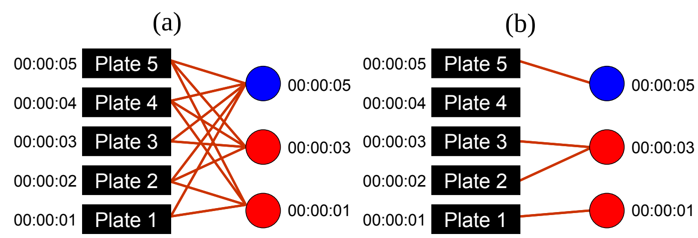

Figure 12. (a) Initial graph.
(b) After eliminate the unnecessary edges.

In addition to the location information of transaction data, we can apply the lane prediction technique [18] as shown in Fig. 4 to estimate the lane ID where the vehicles are taken pictures at. Then the image data and transaction data can be classified by the lane ID. The number of lanes is four, for example, we can divide the original bipartite graph into four subgraphs. This would eliminate the unnecessary edges and decrease the degree of each vertex again. To simplify the bipartite graph would decrease the number of ALPRs that can reduce the human loading to find the illegal vehicles. The impact of the factor to our algorithm will be investigated in simulation.

B. Simulation Environment

The simulation environment is described in this section. In [1], the mobility generator tool is a set of mobility scenario generators including Random Waypoint model, Reference Point Group Mobility model, Freeway mobility model and Manhattan mobility model. The Freeway model is used in our algorithm to generate mobility scenario. The simulation scenario is in a 4 km highway with four lanes. We conduct the simulation using the ns-2 simulator [21] in three scenarios: congested traffic, normal traffic and sparse traffic, and compare the number of ALPRs of orginal bipartite graph and simplified graphs, respectively. The main different parameters among these scenarios are velocity, number of vehicles and acceleration. Table 1 shows the details.

Table 1. Simulation Parameters.

The Length of Highway	4 km
Number of lanes	4 lanes
Number of Vehicles	[4410, 3286, 2519]
Velocity	V_{max}:[108, 80, 54]Km/h V_{min}:[90, 72, 36] Km/h
Acceleration Speed	[0.4, 0.8, 1.2]m/s^2
Simulation times	1800s
Transmission Range	100m
Location of the camera	2000m
Location of the RSU	2000m

In rush hour, the tolerance of the traffic flow in Taiwan ETC is 2,210 vehicles per hour [20]. As shown in Fig. 13, the maximum traffic flow appears from 7 a.m. to 7 p.m., and it is almost 8000 vehicles per hour for all lanes. Electronic toll collection has been implemented in Taiwan for five years. The proportion of illegal vehicles which are not equipped OBUs to total traffic flow is shown in Fig. 14. In recent years, the average error rate is closed to 0.06%. In our simulation, we utilized the error rate from 0.06% to 3.0% in the three scenarios.

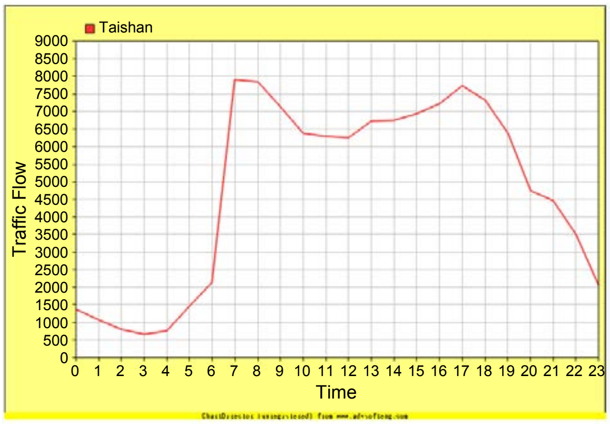

Figure 13. The traffic flow at Taishan Toll Station a day.

http://211.79.135.72/volume/drawday.htm

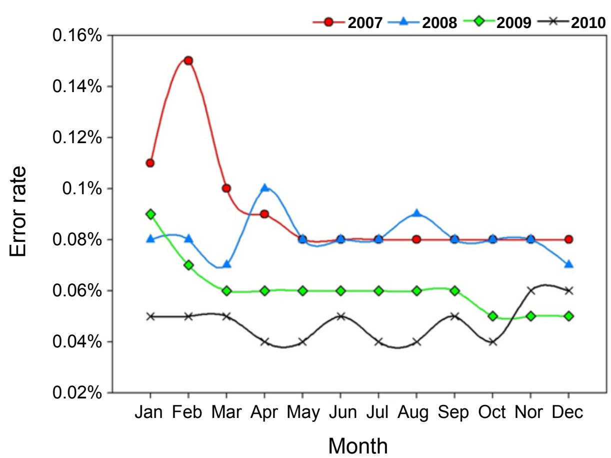

Figure 14. The proportion of illegal vehicles.

C. Result Analysis

In this section, we show the simulation results for the three traffic models in terms of the number of ALPRs, and of the distribution of average degree.

1) Congested Traffic Analysis: Fig. 15 shows the number of ALPRs over different ratios of illegal vehicles and the number is increasing with the growing of the ratio. The origin represents that the input of PT algorithm is the original bipartite graph. The two simplified methods as mentioned in the beginning of this section are named PCL and PCL+PL. The simplified method related to the partition by the camera's location is PCL, and partition by the combination of the camera's location and lane ID is PCL+PL. We can observe that in the worst case, the ratio of illegal vehicles is 3% and the number of ALPRs is almost close to the number of total vehicles in origin. The reason is that our algorithm has to repeat the ALPR step continuously until the number of vertices of the image data set is equal to the number of vertices of the transaction data, or the bipartite graph becomes disconnected. In other words, it has to recognize a large number of image data to achieve the termination condition of the algorithm in congested traffic environment. On the other hand, the simplified bipartite graphs can get better performance than origin. Using PCL and PCL+PL methods, the numbers of ALPRs compared to origin can be reduced by 15% and 60%, respectively. In the bipartite graph simplified by PCL+PL, it is divided into four subgraphs and each lane has its own independent bipartite graph. So PCL+PL can get less number of ALPRs. Fig. 16 shows the number of ALPRs of each lane by utilizing PCL and PL. Obviously, it gets larger when the error rate grows up. In Fig. 17, it shows the distribution of the average degree of the three methods. The average degree of original bipartite graph is more than eight times the average of PCL+PL during 300s to 500s. This claims that the degree is an impact factor for PT algorithm.

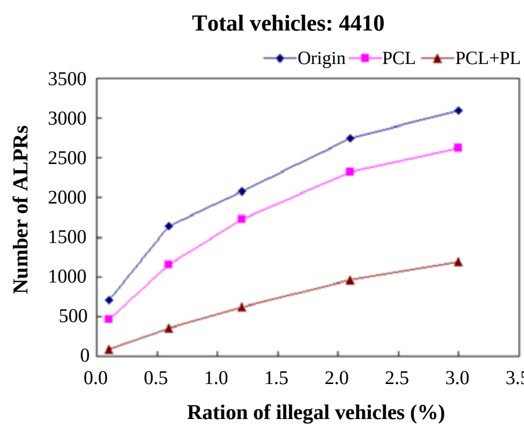

Figure 15. The number of ALPRs in congested traffic.

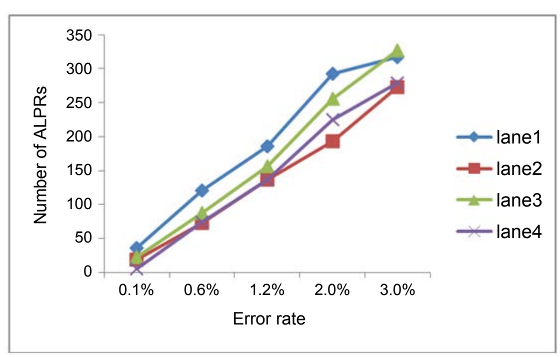

Figure 16. The number of ALPRs of each lane in congested traffic.

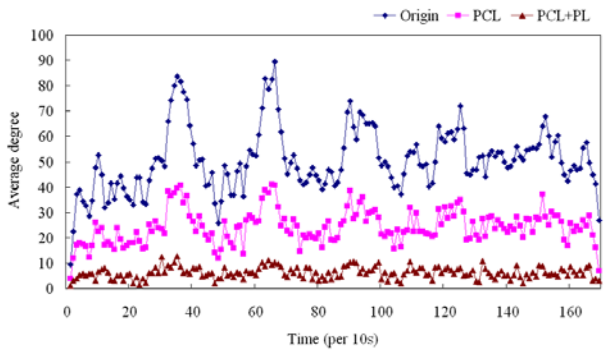

Figure 17. The distribution of average degree in congested traffic.

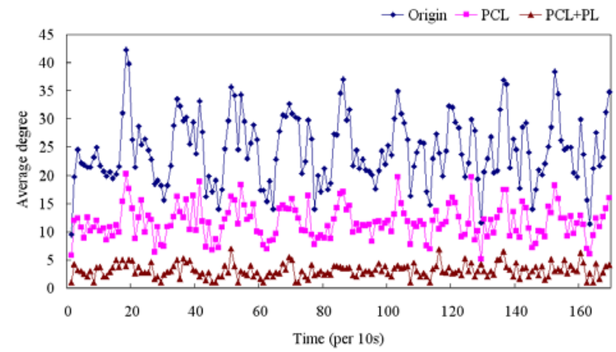

Figure 20. The distribution of average degree in normal traffic.

2) Normal Traffic Analysis： In Fig. 18, it shows that the number of ALPRs of the origin is still half of the total vehicles in worst cast. But, compared with the congested traffic, the ratio number of ALPRs is relatively small. By utilizing PCL and PCL+PL methods, the numbers of ALPRs compared to origin can be reduced by 23% and 80%, respectively. In Fig. 19, it presents the number of ALPRs of each lane by utilizing PCL+PL. The numbers in the worst case of normal traffic are one-third to congested traffic. In Fig. 20, it shows the distribution of the average degree of origin, PCL and PCL+PL. In normal traffic, the average degree is half of the degrees in congested traffic. So the number of ALPRs required in PT algorithm is relatively small.

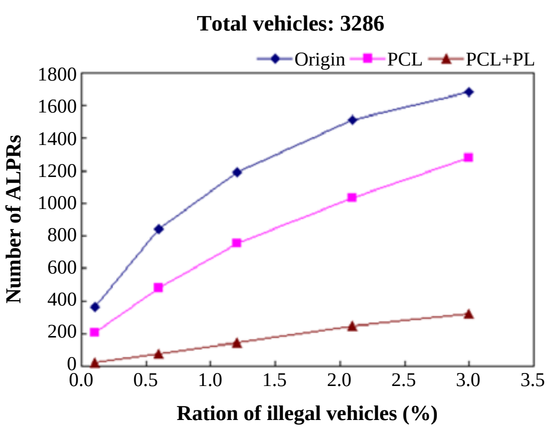

Figure 18. The number of ALPRs in normal traffic.

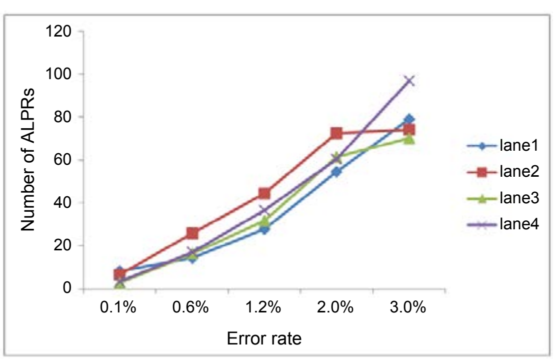

Figure 19. The number of ALPRs of each lane in normal traffic.

3) Sparse Traffic Analysis： Fig. 21 shows the simulation results in the sparse traffic environment. The number of ALPRs is the smallest of three scenarios and it can be reduced by 36% and 87% in the original bipartite graph simplified by PCL and PCL+PL, respectively. Even in the worst case, only five percent of image data need to perform ALPR in PCL+PL method. Since the velocity is faster and the density is lower in the sparse traffic, the degree of each vertex is small. Under this condition, the bipartite graph can more easily be disconnected. In Fig. 22, it presents the number of APLRs of each lane under PCL with PL. Compare to another two scenarios, The number is much lower. In Fig. 23, it shows the distribution of the average degree per ten seconds in the three methods. We observe that all the average degrees in PCL+PL are smaller than five. So PT algorithm doesn't need to recognize many image data in order to disconnect the graph. On the other hand, the enforcement system can create many smaller bipartite graphs in sparse traffic environment, and some of them have exactly the same numbers of vertices of image data set and transaction data set. That is the reason why PT algorithm has a better efficiency in sparse traffic.

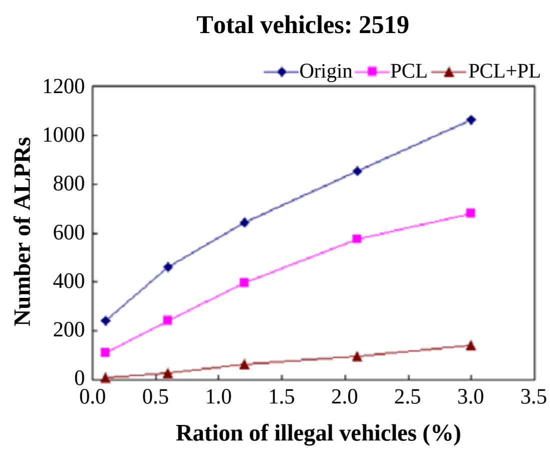

Figure 21. The number of ALPRs in sparse traffic.

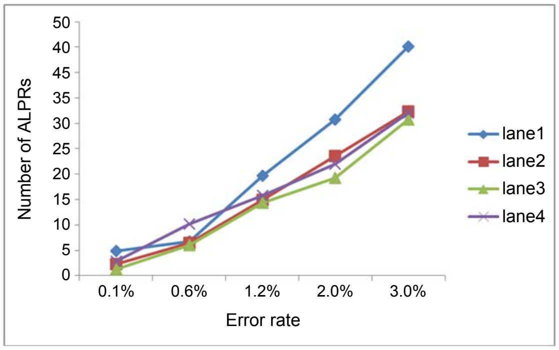

Figure 22. The number of ALPRs of each lane in sparse traffic.

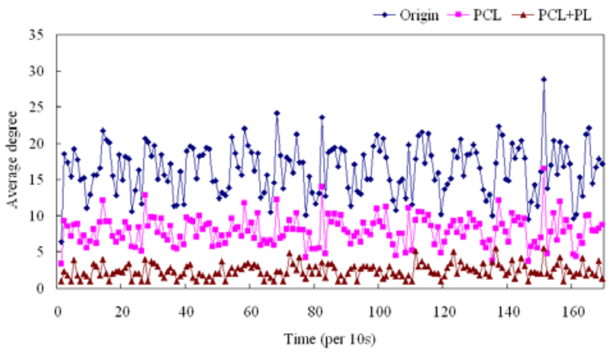

Figure 23. The distribution of average degree in sparse traffic.

***4) The degree Analysis*：** Fig. 24 shows the number of degree in three scenarios with original graph and simplified graphs. The number of degree is the most by exploiting original graph. It seen to has closed number of degree by utilizing PL with PCL in each scenario, but our simulation show the number of degree in dense is ten times more than in sparse. This is because the number of vehicles in dense is much more than in sparse during the same time period. In other words, it has to check as many as vertices so that the bipartite graph could be disconnected.

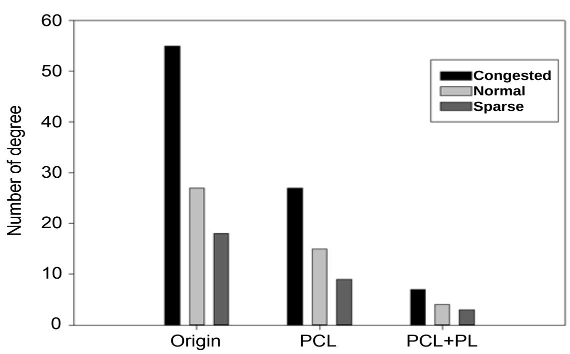

Figure 24. The average number of degree in each scenario.

V. CONCLUSIONS

In this paper, we proposed a Photograph-to-Transaction matching algorithm based on bipartite graph for the violation enforcement of MLFF ETC system. Our algorithm can accurately find all non-payment vehicles and decrease the number of license plate recognitions such that human loading can be reduced. The simulation results shows that the original bipartite graph without simplifying, it has the worst performance in the congested scenario. So we proposed two methods, called PCL and PCL+PL, to simplify the bipartite graph. PCL method is based on the location of transaction data relative to enforcement line, and PCL+PL is based on the lane location where images are captured by cameras. Simulation results show that PCL+PL method has the best performance and the size of degree is an important impact factor. Although our searching method can reduce human loading, there is an important limitation – camera modules must take pictures for every vehicle passing through the enforcement line. How to surmount this limitation is a worth investigation in the future.

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Radio Frequency Identification Networks Planning Using a New Hybrid Evolutionary Algorithm

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Abstract—**The problem of choosing the optimum locations and the associated parameters of readers in RFID communication systems is considered. All these choices must satisfy a set of objectives, such as tag coverage, load balance, economic efficiency, and interference in order to obtain accurate and reliable network planning. In this paper, a novel optimization algorithm, namely the multi-community GA-PSO, is proposed to solve the complicated RFID network planning problem of large-scale system. The main idea of the algorithm is to divide the single population of the canonical PSO into multi-swarm and use the genetic selection and mutation strategy to improve particle swarm dynamic rules. The simulation results show that the proposed algorithm obtains the superior solution for networking planning problem than canonical PSO does.**

Index Terms—**Evolutionary computation, Particle swarm optimization, Radiofrequency identification**

I. INTRODUCTION

Radio Frequency Identification (RFID) as a short-range radio technology for automated data collection is becoming an integral part of our life. The technology is in the ascendant with a concerted effort in recent years to make a further development. Nowadays, an enormous amount of technical and commercial development of RFID has been demonstrated in many industrial applications, such as production automation, anti-theft of merchandises, supply chain management, access control and asset tracking [1]-[2]. The RFID systems consist of two types of devices: unsophisticated, chip, and uniquely-identifiable tags and more powerful electromagnetic readers. RFID interrogators or readers 'senses' the unique identifier and other information stored in RF tags affixed to objects by actively transmitting a signal to communicate with the RF tags [3].

In many applications, the deployment of RFID systems has generated the RFID network planning (RNP) problem that needs to be solved in order to operate the large-scale network of RFID readers in an optimal fashion [4]. However, RNP is one of the most challenging problems that has to meet many requires of the RFID systems. In general, the RNP aims to optimize a set of objectives (coverage, load balance, economic efficiency and interference between readers) simultaneously by adjusting the control variables (the coordinates of the readers, the number of the readers, and the antenna parameters, etc.) of the system [5]. As other wireless communication systems, the network planning is a nonlinear optimization problem and has aroused many researcher' interest. Recently, many studies have been carried out and a large number of approaches have applied in the literature. In [6]-[7], the method for optimal placement of readers is proposed mainly based on the coverage constraint. The work in [8] focuses on the scheduling problem in which the heuristic algorithm is used to solve the interference problem. A load balance problem is rigorously researched in [9] and the minimum multiprocessor scheduling (MMS) algorithm and the maximum network flow (MNF) algorithm is used to solve the load balance problem. In [10], the authors combine the main constraints to propose a combined measure to present an overall optimal solution for the RNP problem.

For the possible combination of RFID reader positions are too numerous, the exhaustive optimization of the nonlinear optimization problem demands an impractically tremendous computational effort which leads to the application of the heuristic algorithm in the filed. The particle swarm optimization and genetic algorithm usually work in a population which search around the solution space by some operators until finding the optimal solution. However, in nature, the common feature of many social networks is community structure, the tendency for individuals to divide into groups, with dense connections within groups and only sparser connections between them [11]. A number of recent results suggest that networks can have properties at the community level that are quite different from their properties at the level of the entire network, so that analyses that focus on whole networks and ignore the community structure may miss many interesting features [12]. Indeed, in biological populations there is a continuous interplay between individuals of the same species, and also encounters and interactions of various kinds of with other species [13]. Inspired by the community structure cluster phenomenon, we extend the single population to the interacting multi-community structure in the heuristic algorithm and combined the genetic strategy and particle swarm dynamic rules to propose a multi-community GA-PSO algorithm. Then the algorithm is applied into the RNP problem compared with canonical PSO to validate the effectively of the proposed method.

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An outline of this paper is as follows. In Section II, the formulation model for the network planning in RFID networks is introduced. Section III gives brief reviews of the canonical PSO and the genetic algorithm and then presents the proposed multi-community GA-PSO algorithm in details. In Section IV and Section V, the proposed solution procedures for solving the RNP problem using multi-community GA-PSO algorithm is presented. In Section IV, the propagation pattern of reader is circle and in Section V the propagation pattern of reader is ellipse and corresponding simulation results in two different propagation pattern are illustrated. Finally, in Section VI concluding remarks are stated and ideas are proposed for further research.

II. RFID NETWORK PLANNING PROBLEM FORMULATION

In this section, the formulation and some basic elements for RFID network planning are presents. This model simplifies the complexity of spatial transmission of electromagnetic waves. The up-link signal constraint, which ask for the backscatter signals reflected by tags must be received by a reader, is reasonably omitted by increasing the signal threshold size.

A. Propagation Model

In order to calculate the signal strength at each tag, a radio wave propagation model is needed. Such a model is used to compute the propagation loss of an electromagnetic field between a reader and a tag. In many cases, RFID is used in an indoor environment such as production management and anti-theft of merchandises. In this paper, the propagation model on indoor communications [4], [14] is employed:

$$P_{tag} = P_{reader} - L[dB] \tag{1}$$

$$L = 10\log[(4\pi/\lambda)^2 d^n / G_{reader} G_{tag}] + \alpha[dB] \tag{2}$$

Where P_{tag} is the power output by the RFID reader, L is the propagation loss considering multipath fading, n is between 1.5 and 3, α is about 10dB in the worst case and G_{read} and G_{tag} are reader antenna gain and tag antenna gain respectively [4].

B. Readers and Tags

In RFID systems, the RFID readers communicate with the tags by reading/writing the information stored on them. In most cases, the tags are passive and low functionality which means the tags receive power from a reader to operate and then transmit the backscatter signal to the reader. However, the reader has a limit on its interrogation range. If the radio signal received at a tag is higher than a quality threshold, noted R_q hereafter, then the communication between the reader and tag can be established. For the power needed for a tag transmitting the backscatter signal back to the reader is taken from the received power, the threshold in this discussion is reasonably set higher than the rated value which is dependent on the type of RF tags considered and carrier frequency.

As for the reader, we take the power-adjustable antenna to make the optimization problem more flexible. The emitted power is adjusted by the attenuation. In this paper, the problem only concerns the variables of the position and radiated power of the RFID readers serving the working area.

C. Coverage

In the RNP optimization problem, the first objective function represents the level of coverage, which is most important in the RFID systems. For that if any large amount of tags cannot be read by any reader, the RFID systems will be no practical use. Before define the coverage constraint and other constraints, as well as to define the mathematical formulation for optimization, some basic notations are formulated:

- R_q : received power threshold guaranteed reader-to-tag communication
- $P_{r,t}$: the field strength received at a tag t from a reader r
- ST : set of all tags in the working area
- SR: set of the reader serving the area
- $C_v(r)$: the set of tags served by reader r, which is defined [4] as:

$$C_v(r) = \{t \in ST \mid P_{r,t} \geq R_q, \forall r' \in SR, r' \neq r, \quad P_{r,t} \geq P_{r',t}\} \tag{3}$$

Then the constraint can be formally expressed by the following formula equations:

$$ST = \bigcup_{r\in SR} C_v(r) \tag{4}$$

In order to define a measure to facility the calculation, the function f_1 is defined as follow:

$$\max \quad f_1 = N_{coverag} / |ST| \tag{5}$$

where $N_{coverage}$ is the number of tags covered by all readers, |ST| is the number of total tags which is used to normalize performance indicators.

D. Interference

Reader interference mainly occurs in a dense reader environment, where several readers try to interrogate tags at the same time which will result in an unacceptable level of misreads. The reasonable planning of networks will reduce the interferences and improve the Quality of Service. In order to estimate the interference level, each tag's best service reader should be predicted. Thus, for a tag, the sum of received signals which are less than $Cd_{r,t}$, which represents the best signal received at a given tag t covered by the reader r, and greater than the required sensitivity threshold S_m can stand for interference in a certain sense [4]. Hence, the interference level at tag t is given by:

$$\gamma(t) = \sum (P_{r',t} - S_m), \quad Cd_{r,t} \geq P_{r',t} \geq S_m \tag{6}$$

The objective of minimizing the total amount of interferences can be expressed as follows:

$$\max \quad f_2 = \sum_{t\in ST} (Cd_{r,t} / (Cd_{r,t} + \gamma(t))) / |ST| \tag{7}$$

It is the optimal condition when f_2 equals to 1, in that case the interference level returns to zero.

E. Load Balance

For various performance measures, it is important to design effective load balancing schemes for distributing tags among readers as evenly as possible [5]. In [9], the author formulated the planning problem into a bipartite graph G=(U ∪ V,E), where U equals to SR and V denotes the set of tags, equivalent to ST defined before, E donates the set of edges between reader and tag if and only if they can communicate with each other. Each edge has a non-negative energy cost $c_{i,j}$ representing the energy cost of reader r_i to read tag t_j once. Then the problem definitions in [9] is to find an assignment $\Phi : V \rightarrow U$ of each tag t_j to a reader $r_i = \Phi(t_j)$ such that the maximum of the total energy cost:

$$C_i = \sum_{r_i=\phi(t_j)} c_{i,j} \quad (8)$$

over all readers is minimized. To simplify our discussion, the energy cost has a fixed unit energy cost, namely $c_{i,j}=1$, then the load balance constraint become:

$$\min \quad C_i = n_i \quad (9)$$

n_i is the number of the tags assigned to reader r_i. The constraint, in other words, is to balance the number of tags assigned to each readers as far as possible. For facilitating the calculation and presenting the fitness function, some measures have been proposed.

The mean square deviation method is to calculate the covariance of the numbers of tags and the lower value indicates the higher equilibrium of the tags assignment. The formula is as below:

$$D(X) = 1/|SR| \times \sum (n_i - E(n))^2 \quad (10)$$

when the label distribution is uniform, this method can achieve minimum value. However, if the n_i not equal to the average number of tag, or all reader are assigned the same number of tags but equal to a small number, for instance 1, the value of D(X) also equal to zero. That is, the measurement only can reflect the balance of tags assigned to reader, but can only be used under the maximum coverage rate premise.

Also the product of n_i is another approach, in that way, the indicator obtains maximum value if and only if in the situation that equal distribution of the label. The formula is as below:

$$\max \quad f = \prod n_i \quad (11)$$

However, this method has the shortcomings of hard to be normalized.

In information theory, entropy is a measure of the uncertainty associated with a random variable. Entropy is a state function of the system; it can be used to describe the state of existence of a certain system, and its changes can also be used to indicate the direction of the evolution of the system. Since 1850 when Clausius put forward the second law of thermodynamics and 1865 when he introduced the state function, entropy and accurately proved the principle of entropy increase in mathematical terms, the concept of entropy has been quickly extensified with swift extension to other disciplines, an extremely strong capability of its development to many fields.

When studying the efficiency of communication system, Shannon introduced the concept of information entropy based on the basic concept of thermodynamics entropy [25], which was defined as:

$$S = -\sum P_i \log P_i \quad (12)$$

P_i is the probability of the *i*th basic event. Here, entropy reflects the degree of a certain "uncertainty" in the state of the system. And the entropy difference of system change provides us with a message like this: RTIE is closely related to matter, energy and information conversion; entropy can be regarded as an important variable for the description of the RTIE. For a complex system such as the RTIE, entropy will not only reflect its state, but also show its uniqueness [24].

Take the form of the information entropy function S, the load balance constraint measurement f_3 is defined using the entropy concept as follows:

$$\max \quad f = -\sum_{i=1}^{|SR|} (n_i/|ST|) \ln(n_i/|ST|) \quad (13)$$

where |SR| is the number of total readers and |ST| is the number of total tags. The form of $n_i/|ST|$ takes the form of P_i, the probability of *i*th basic event. To normalize the measurement, the term ln(|SR|) is used and the performance indicator is as below:

$$\max \quad f_3 = -\sum_{i=1}^{|SR|} (n_i/|ST|) \ln(n_i/|ST|) / \ln(|SR|) \quad (14)$$

then the measurement can achieve maximum value 1 if and only if each reader was assigned the same number of tags.

F. Combined Measures

The overall optimal solution for RNP is represented by a linear combination of the three objective functions:

$$\max \quad f = \sum_{i=1}^{3} \omega_i f_i; \quad \omega_1 + \omega_2 + \omega_3 = 1 \quad (15)$$

The weight values of each objective function can be flexible varied to account for any specific situation.

III. Multi-Community GA-PSO

A. Basic Concepts of GA and PSO

Genetic algorithm is stochastic search procedures based on the mechanics of natural selection, genetics, and evolution [15]. The individual, or chromosome, is a potential solution which searches in the solution space by three operators - selection, crossover and mutation to find the global best solution. Particle swarm optimization is also a kind of algorithm to search for the best solution by simulating the movement of birds flocking. The particle, akin to the chromosome in GA, updates according to the dynamic rules until the entire particles converge to the optimal solution. However, both canonical PSO and GA both operate in the same population, whereas in the natural world, social community structure is commonly existent in the network [11] and interactions between groups of the same species are easily observed. Inspired by the community structure phenomenon, we extend the single population in the heuristic algorithm to the interacting multi-community structure and propose multi-community GA-PSO.

B. The Hybrid Algorithm of Multi-community GA-PSO

Community organizational structures extensively emerge in many biological, social, man-made engineering systems. In these organizations, all the members are divided into some groups, and it has been demonstrated that the hierarchical structure can be organized more efficiently and thus can address larger scale problem [16].

The multi-colony or multi-swarm PSO algorithm is proposed by many researchers base on the concept of dividing single population into many colonies and the individuals cooperate with each other to achieve the global optimum solution [5],[17]-[22]. The proposed method, however, simulates the mutation and selection phenomenon in nature colony and adds the corresponding operator in the single community to better mimic the natural laws of population.

In the proposed algorithm, the population is divided into some communities. The individuals in the same community can share information with each other and construct a fully connected topology, and all the communities form a ring topology, among which each community can exchange the global best solution found in adjacent group. The topology schematic diagram is shown in Fig. 1.

In this case, each individual of the proposed model evolves based on individual's own cognition, social interaction within each community and information exchanged from other communities. The main parameters and operators of the novel GA-PSO algorithm are described as below.

1) Coding and Initialization: Coding cares about how to represent the practical parameters of the optimization problem into an individual. The novel algorithm adopts the floating point coding scheme. At the beginning of the algorithm, all the individuals in the population should be generated initially and are uniformly distributed random numbers in $[X_{min}, X_{max}]$, where X_{min} is the lower limitation of the particle position and X_{max} is the upper limitation. At the same time, the velocity of the particles should be initialized at first, within the limit of $[V_{min}, V_{max}]$.

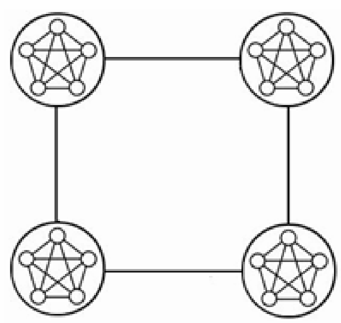


Fig. 1. The topology schematic diagram

2) PSO Updating Rule: In the proposed method, the individual updates the position and velocity according to three guides. The enhanced dynamic rules are formulated as:

$$\vec{v}_i^k(t+1) = \omega\vec{v}_i^k(t) + c_1 r_1[\vec{p}_i^k(t) - \vec{x}_i^k(t)] + c_2 r_2[\vec{p}_g^k(t) - \vec{x}_i^k(t)] + c_3 r_3[\vec{p}_g^m(t) - \vec{x}_i^k(t)] \quad (16)$$

$$\vec{x}_i^k(t+1) = \vec{x}_i^k(t) + \vec{v}_i^k(t+1) \quad (17)$$

where ω is the inertia weight; c_1, c_2 and c_3 are the acceleration constants with positive values; r_1, r_2 and r_3 are uniformly distributed random numbers in [0, 1]; the superscript in each item represents the serial number of community and the subscript indicates the label of individual in corresponding community. The vector p_i^k represents the individual's best position in history in its own community; p_g^k represents the global best position founded in k^{th} community; p_g^m represents the global best position founded in m^{th} community, where k^{th} and m^{th} community are adjacent.

3) Selection Operator: In order to produce well-performing individuals in the novel algorithm, the selection mechanism is adopted in each group. In each generation, after the fitness values of all the individuals in the same community are calculated, the low half worst performing individuals are marked out. Instead of replacing the worst-performing individuals with the top-half well-performing individuals [23] in the same group, the paper only replaces the worst performing one with the previous community's global best position $p_g^k(t-1)$ in order to accelerate the convergence speed.

4) Mutation operator: In Multi-community GA-PSO, mutation occurs after the velocity and position update operator. Mutation is an operator derived from the mimic of biological genetic breeding behaviour and by the operator, the apposition of an individual is altered randomly so that new genetic materials can be introduced into the population. In the proposed method, the mutation operator can be used to overcome the premature convergence. Here, uniform mutation is adopted, that is, the mutated gene is drawn randomly, uniformly from the corresponding search iteration. In the following simulations, a constant mutation P_m probability is used. The mutation operator rests the individual's position by re-initialized the position randomly in the searching space. Compare with traditional methods by which the individual adds a stochastic disturbance to the original position, the method taken in the work is somehow a large scale operation in order to avoid the premature phenomenon.

IV. Circular Propagation Model Simulation

In this section, multi-community GA-PSO is applied to the RFID network planning problem compared with canonical PSO. For RNP problems, the object is to place readers at the best position while optimizing a set of objectives- coverage, load balance and interference between readers simultaneously. To demonstrate the superiority of the proposed algorithm, in simulation, the performance of the proposed algorithm is compared with the canonical PSO.

A. Simulation Scenario

The RFID planning working area is simulated by an ideal square scene (25m×25m) with 80 tags, which are randomly distributed in the working area. Ten radiated-power adjustable RFID readers are considered to cover this working area. Fig. 2 shows the ideal square working area.

B. Parameter and Procedure

For Multi-community GA-PSO, all the individuals forming the whole population should be randomly generated into ten communities, and each community contains ten individuals with random positions and velocities. Each individual in the algorithm takes a floating point coding scheme and has a dimension equal to 3×|SR|, in which the first 2×|SR| elements in the individual vector indicate the coordinates of reader positions, and the |SR| elements in vector dimensionalities for radiated powers of each reader. The inertial weight starts at 0.9 and linearly decreases to 0.4 with the increment of the iteration. The acceleration constants c_1, c_2 and c_3 are set to 1.494, the mutation probability constant P_m is set to 0.1 and the maximal epochs is 500.

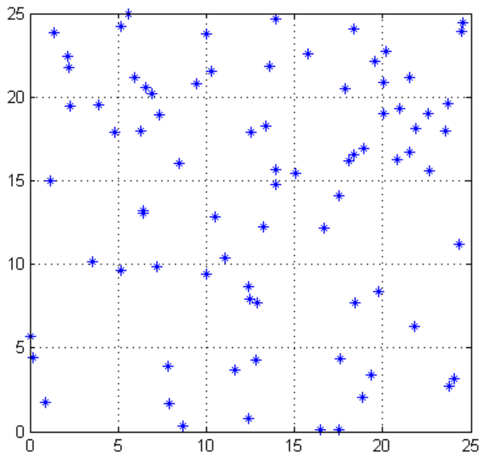


Fig. 2. The square working area

Then the detailed procedures for this algorithm can be summarized as follows:

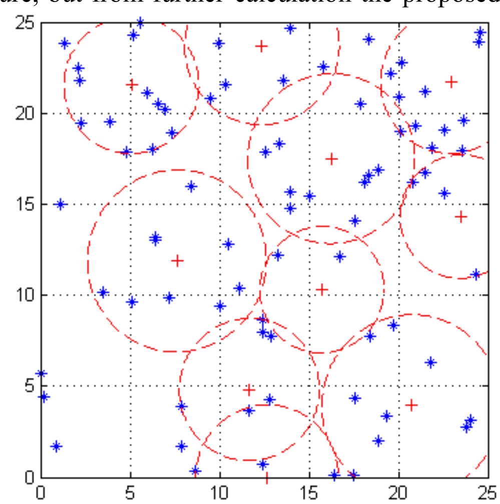
- **Step1**. Initialize the positions and velocities of the whole population of ten communities randomly and set parameter values as described before.
- **Step2**. Evaluate each particle's fitness value using (11) in each group then record each particle's best position P_i^k. Then calculate the global best position P_g^k in each community.
- **Step3**. The position and velocities of all the particles are updated according to (16) and (17). If the new particle's position and velocity are beyond their respective limitation, the value must be set as the nearest boundary.
- **Step4**. Based on the mutation strategy, each particle in each community will mutate according to certain probability P_m, and then produce the new population.
- **Step5.** Evaluate each new particle's fitness value and compare each individual's new fitness value with the previous best record. Then update the particle's best position and the global best position in each group.
- **Step6.** After the fitness values have been calculated, the worst performing individual in each community is marked out. By selection operator, the worst performing individual is replaced by the previous global best position in its community with its current velocity and historical best position unchanged.
- **Step7.** If the maximal iterative generations are achieved, or the global best position's fitness value has achieved the setting precision, it is the ends of the algorithm, else, go to Step 3.

To illustrate the effective of the new algorithm, traditional PSO is used as a comparison. For PSO, the inertia weigh takes the same dynamic value with the proposed algorithm, the acceleration constants c_1 and c_2 are set to 1.494, the population size is 100, and the maximal epoch is 1000.

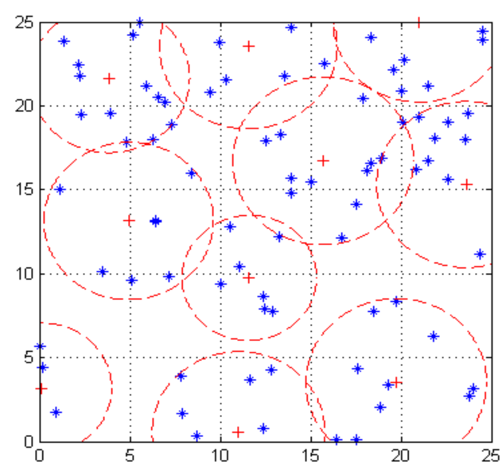
C. Simulation Result

The final network planning results found by two algorithms is presented in Fig. 3 and the fitness of optimization process is shown in Fig. 4.

The red dotted line in Fig. 3 indicates the power threshold R_q, and the plus symbol represents the coordination of each readers. The electromagnetic field strength in the circle descends according to the distance to the reader, however for clarity it is simplified, then the tag in the two circle sphere need to be calculated the received power to determine which reader it belongs to. From the comparison of Fig. 3-(a) and Fig. 3-(b), we can easily observe that the multi-community GA-PSO algorithm can obtain a completely coverage that no tag is neglected by readers. In the dense regions of tags, the tags are distributed to different readers in Fig. 3-(b) to satisfy the load balance constraints while in Fig. 3-(a) all the tags in the dense region belong to one reader. The interference level, however, cannot deduce from the figure, for the power is not depicted in the picture, but from further calculation the proposed method



(a)



(b)

Fig. 3. Experimental results (a) traditional PSO algorithm; (b) Multi-community GA-PSO algorithm

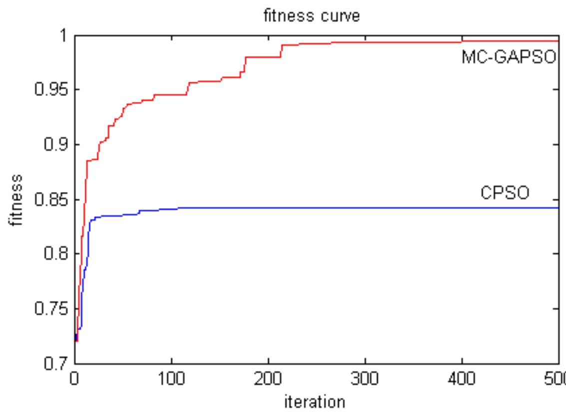


Fig. 4. Fitness curve

also achieves better performance.

Seen from the Fig. 4, the new algorithm is apparently better than the traditional method. The novel algorithm can avoid premature phenomenon while the searching is stagnated in traditional PSO at early iteration. The novel algorithm can keep the diversity of the population and achieve better fitness value, provided verification for the optimized approach.

V. Ellipse Propagation Model Simulation

The reading range is one of the most critical performance indicators of radio-frequency identification (RFID) systems. It depends on many physical and geometrical parameters. Typically, in the ultra-high-frequency band, the maximum size of the reading region is estimated by the free-space propagation model. This is based on the Friis formula, even if much more accurate predictions may be accomplished nowadays by time-consuming electromagnetic simulations, accounting for the antennas and the interaction with the nearby environment [30].

In RFID system, the propagation pattern of RFID reader antenna equal to the space electromagnetic field distribution model of wireless antenna which in some research literature known as identify region [26] .

The RFID reader antenna propagation model is determined by many parameters: the reading and writing of the antenna power, the antenna attenuation value, radio frequency band, tag threshold power, etc. Although communication model calculation is a complicated process, but once these parameters of the RFID system is known, it can through the ray tracing method or the actual way of reading and writing tests to determine the antenna to reading and writing the scope of the label.

The method to classify the pattern of the RFID reader is plenty of, but the most commonly used method is classifying the pattern by its geometric shape and then the pattern is classify into circle pattern and ellipse pattern.

In recently, the type of antenna in used is patch antennas, also known as micro-strip antenna. According to antenna theory, if take the main lobe of antenna signal as the effective coverage areas, then antenna coverage is an approximate the elliptical shape [27-28]. In [29], the author through the antenna electromagnetic field analysis and experimental way, verify the RFID for reading and writing the spread of antenna model roughly into an oval.

In short, the patch antenna of the RFID reader is directional, considering the antenna in the plane of the cover, the coverage area is not a round, so in the deployment of the antenna when RFID can't cover simple with a round instead of, and need to consider the direction of the antenna.

A. Simulation Scenario and the Ellipse Model

In ellipse propagation pattern simulation, the RFID planning working area is as same as the scene of the circle propagation simulation as shown in Fig. 2.

To simplify the calculation process, the reader used in the section is different from the previous ones. The reader has the range of interrogation in an ellipse shape, with fixed length of long axis of 5m and fixed length of short axis of 4m. That means the power of the reader is not adjustable. Considering the direction of the reader, while in the circle propagation the direction make nothing different, then the dip angle of this type is considered as a variable quantity to be optimum.

B. Parameter and Procedure

In the oval propagation pattern, all the individuals forming the whole population should be randomly generated into ten communities, and each community contains ten individuals with random positions and velocities as like in the circle simulation. However, the coding strategy is somehow different from the former simulation.

Each individual in the ellipse simulation takes a floating point coding scheme and has a dimension equal to $3\times|SR|$, in which the first $2\times|SR|$ elements in the individual vector indicate the coordinates of reader positions, and the $|SR|$ elements in vector dimensionalities for the of angle with the horizontal direction of each reader. The angle is illustrated in Fig. 5.

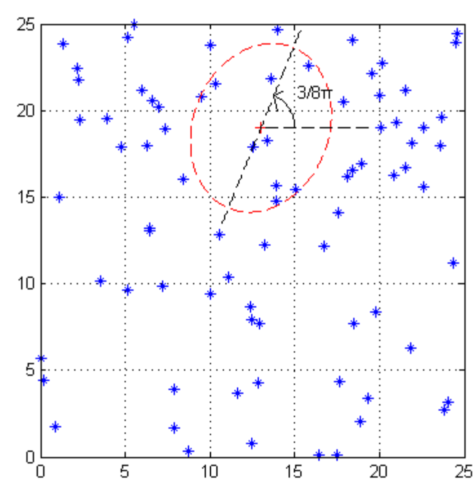


Fig. 5. The ellipse propagation pattern

The inertial weight starts at 0.9 and linearly decreases to 0.4 with the increment of the iteration. The acceleration constants c_1, c_2 and c_3 are set to 1.494, the mutation probability constant P_m is set to 0.1 and the maximal epochs is 500. For the new model only change the propagation of RFID reader, the optimum algorithm apparently will not be modified

C. *The fitness value calculation*

It is apparently that the fitness calculation is somehow a handicap to solve. In this section, the simplified distribution model of electromagnetic field is shown and the method to calculate the fitness value is illustrated.

Coordinate rotation transformation

The propagation pattern is in ellipse shape that it is not easily solvable in the circle pattern, in which the tags receive power can be calculate by its distance from the reader. Any tag that has the same distance to a reader must have the same receive power. However, in ellipse model, two tags have the same distance to a reader, one in the long axis direction while on in the short axis direction, but the one in the short direction may not be covered by the reader.

Considering the ellipse general equation may take large amount of calculation, while in contrast the calculation of the position of tag is easy to solve, then in this paper, when calculate whether a tag is covered by a reader and the power by simplified calculation, all the tags' position are rotated according to the angle of the ellipse.

Take an example for instance; individual in the algorithm has a dimension equal to 3×|SR|, in which the first 2×|SR| elements in the individual vector indicate the coordinates of reader positions, and the |SR| elements in vector dimensionalities for radiated powers of each reader. That is the individual is in the form of $[x_1,y_1,x_2,y_2,\ldots,x_9,y_9,x_{10},y_{10},\theta_1,\ldots,\theta_{10}]$. Considering the speed and position limit in PSO update rules, the angle of reader variant is separated from its position [x, y] variants such that the individual updating rule is simplified.

Take the *i*th reader's position x_i and y_i and the 20+i element of the particle vector – the angle of the reader θ_i, for instance the i equal to one and the corresponding coordination and angle is [10, 15, 0.25π], then the ellipse is depicted in the area, as shown in Fig. 6.

Then process the coordinate rotation transformation and translation transform, then the area is shown in Fig. 7.

It is easily seen that the relative position of the reader and tags without change, the tags that in the coverage area are still in the domain. But after the coordinate rotation transformation, the coverage area is an ellipse standard equation as below:

$$x^2/a^2 + y^2/b^2 = 1 \tag{18}$$

where the length of the half long axis equal to 5m and the length of the half short axis equal to 4m in this paper.

Coverage rate calculation

After the position transformation, the tags' positions are in a new coordination, but the node indicator does not change. Then put node coordinates into the ellipse standard equation, if the coverage rate, namely the f1, will be calculate by the numbers

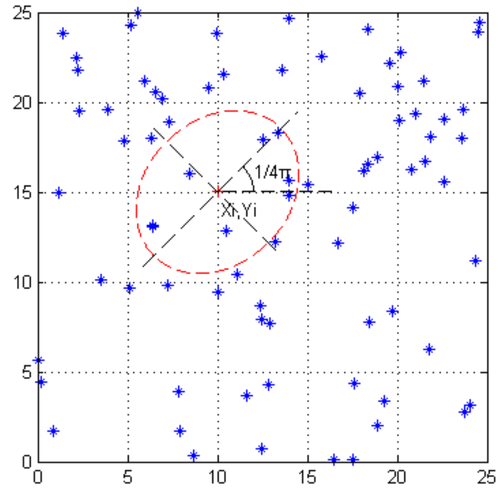


Fig. 6. The reader position and angle

of tags covered by ten readers divided by the total value less than or equal to one, the tag is covered by the reader.

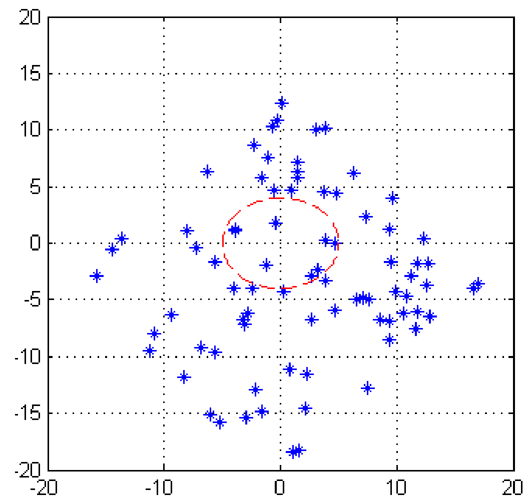


Fig. 7. The coordinate rotation transformation

Do the process again for other nine readers, then the number of tags. The detail description can be seen in Algorithm 1.

Algorithm 1 Coverage rate (CR) calculation

For i=1:1:10
  Transformation (position); //transformation the tag position
  Rotation (position);
  For j=1:1:80
    $value = x^2/25 + y^2/16;$
    status (j,i)=value;
    IF value<=1 **THEN**
      coverage(j)=1;
    END IF
  END FOR
END FOR
f1=sum(coverage)/80;

Load balance rate calculation need to know the number of tags a reader assigned. If a tag is covered by more than one reader, then the tag belongs to the reader which transmits the max power on it.

In the load balance calculation, put node coordinates into the ellipse standard equation and calculate the value. If a tag has the minimum value from a reader, then the tag is assigned to the reader.

The detail description can be seen in Algorithm 2.

Algorithm 2 Load balance rate (LB) calculation

```
For i=1:1:10
   Transformation (position); //transformation the tag position
   Rotation (position);
   For j=1:1:80
      value = x^2/25 + y^2/16;
      status (j,i)=value;
   END FOR
END FOR
FOR i=1:1:80
   [maxpower, indicator]=min( status(i,:) );
   IF maxpower<1 THEN
      assign(pos)=assign(pos)+1;
   END IF
END FOR
SET sum=0
FOR i=1:1:10
   sum=sum-( assign(i)/80 )*log( assign(i)/80 )/log( 10 );
END FOR
f3=sum;
```

However, the calculation of interference level needs to know the interference signal that other readers transmit on it. The reasonable planning of networks will reduce the interferences and improve the Quality of Service. In order to estimate the interference level, each tag's best service reader should be predicted.

Similar to the load balance algorithm, the max power $Cd_{r,t}$, which represents the best signal received at a given tag t covered by the reader r, can be determined by the value of ellipse standard equation. However, the value can reflect the strength of the power of the tag received by a reader, but it can not directly be calculated as the signal. In this paper, the calculation is simplified by considering the power inversely proportional to the value. Under this assumption, the pseudo code of the algorithm is as blew:

Algorithm 3 Interference rate (IR) calculation

```
For i=1:1:10
   Transformation (position); //transformation the tag position
   Rotation (position);
   For j=1:1:80
      value = x^2/25 + y^2/16;
      status (j,i)=value;
   END FOR
END FOR
FOR i=1:1:80
      [maxpower, indicator]=min( status(i,:) );
      temp=status(i,:);
      FOR k=1:1:10
         IF temp(k)==0
            temp(k)=0.01;
         END
         IF temp(k)>1
            temp(k)=0;
         ELSE temp(k)=1/temp(k);
         END
      END
      r_(i)=temp(indicator)/sum(temp);
END
SET sum=0
FOR i=1:1:80
   sum=sum+ r_(i);
END FOR
f3=sum/80;
```

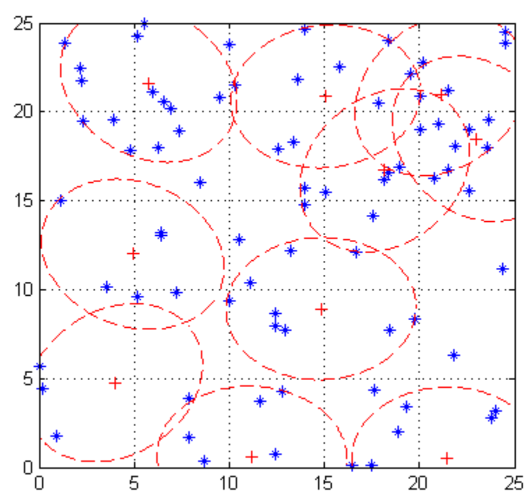
D. Simulation Result

In the ellipse simulation, the weight values of each objective function take the value of [0.7 0.1 0.2], then the fitness function is defined as blew:

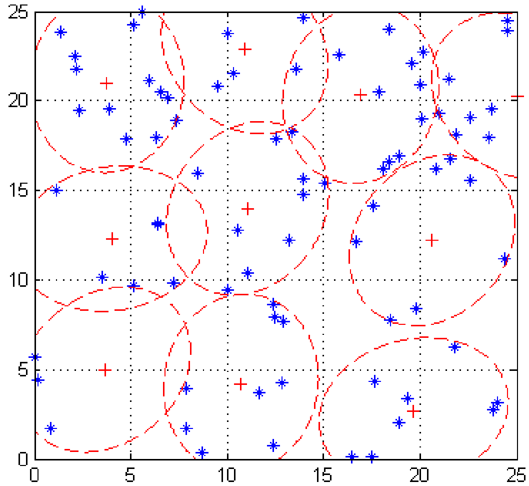
$$f = 0.7f_1 + 0.1f_2 + 0.2f_3 \tag{19}$$

The basic parameter in the ellipse simulation is similar to the circle propagation simulation and the permissible error is set 0.01.

The final network planning results found by traditional PSO and the multi-community GA-PSO is presented in Fig. 8 and the optimization process is shown in Fig. 9.



(a)



(b)

Fig. 8. Ellipse model simulation results (a) traditional PSO algorithm; (b) Multi- community GA-PSO algorithm

The red dotted line in Fig. 8 indicates the power threshold R_q, and the plus symbol represents the coordination of each readers. The electromagnetic field strength in the circle descends according to the ellipse propagation model, however for clarity it is simplified, then the tag in the two circle sphere need to be calculated the received power to determine which reader it belongs to. From the comparison of Fig. 8-(a) and Fig. 8-(b), we can easily observe that the multi-community GAPSO algorithm can obtain a completely coverage that no tag is neglected by readers. In the dense regions of tags, the tags are distributed to different readers in Fig. 8-(b) to satisfy the load balance constraints while in Fig. 8-(a) all the tags in the dense region belong to one reader. The interference level, however, cannot deduce from the figure, for the power is not depicted in the picture, but from further calculation the proposed method also achieves better performance. Also seen from the upper right corner of the region, the reader are clustered, the interference level must be high.

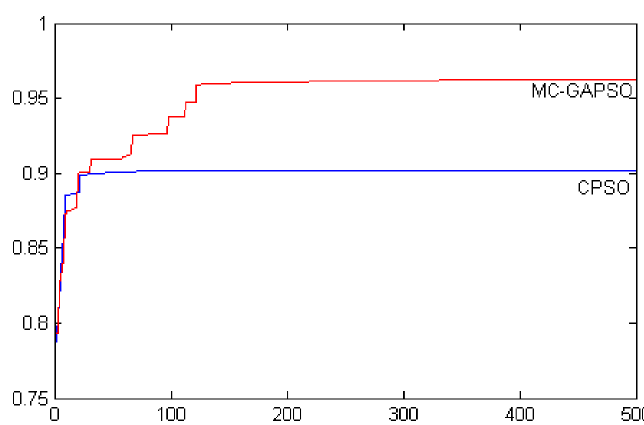


Fig. 9. Fitness curve in ellipse model

Seen from the Fig. 9, the proposed algorithm is apparently better than the traditional method. The novel algorithm can avoid premature phenomenon while the searching is stagnated in traditional PSO at early iteration. The climacteric of the fitness curve indicate the algorithm are stagnated by the mutation operator add new best individual to the population. The novel algorithm can keep the diversity of the population and achieve better fitness value, provided verification for the optimized approach.

For testing the performance of GA-PSO, we use other ten different patterns which are randomly generated in a two-dimensional square scene (25m×25m) with 80 tags. The simulation results are listed in Table I.

TABLE I
SIMULATION RESULTS OF TEN DIFFERENT PATTERNS

No. of patterns	GA-PSO			CANONICAL PSO		
	CR	LB	IR	CR	LB	IR
1	0.94	0.92	0.93	0.85	0.83	0.86
2	0.95	0.92	0.94	0.85	0.83	0.88
3	0.94	0.92	0.94	0.83	0.82	0.87
4	0.93	0.91	0.92	0.82	0.81	0.81
5	0.96	0.95	0.95	0.89	0.88	0.89
6	0.96	0.94	0.95	0.89	0.86	0.88
7	0.94	0.91	0.95	0.82	0.81	0.8
8	0.96	0.92	0.95	0.85	0.83	0.84
9	0.92	0.90	0.92	0.82	0.80	0.81
10	0.93	0.91	0.91	0.83	0.82	0.82

In Table I, the abbreviations CR, LB and IR denote coverage rate, load balance rate and interference rate, respectively. These performance indexes are normalized so that the closer to 1, the better the values are. For each tag distribution pattern, the two algorithms run 10 times respectively, so Table I gives the mean values of the performance indexes averaging over 10 runs. It shows that the GA-PSO algorithm finds better solution for all these ten tags distributing patterns, which has better performance indexes denoted by coverage rate, load balance rate and interference rate than the canonical PSO dose.

VI. CONCLUSIONS

In this paper, an optimization model for planning the position of readers in the RFID network is proposed. The RFID network planning problem is a multi-objective nonlinear optimization problem, and a multi-community GA-PSO algorithm is presented to find the optimum configuration for RFID readers deployment while satisfy coverage, interference and network load balance Constraints.

Finally, although the simulation results show the novel algorithm's effectively, some comments on the future research are given. The algorithm is a static algorithm which can only apply for a certain sense, the propagation model can further be consummated, and the way of setting parameters of the novel algorithm needed to be considered and moreover the novel algorithm remains to be examined for other complicated optimization problem.

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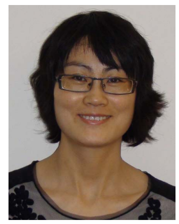

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The current research interests are intelligent optimization methods, RFID system and its application in supply chain and the control systems and dynamics.

Ontology-based Multimedia Contents Retrieval Framework in Smart TV Environment

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***Abstract*—Semantic search promises to provide more accurate result than present-day keyword matching-based search by using the knowledge represented logically (i.e., knowledge base). But, the ordinary users don't know well the complex formal query language and schema of the knowledge base. So, the system should interpret the meaning of user's keywords. Such requirements are conspicuous especially in smart media such as smart phone, IPTV and smart TV. In this paper, we describe a framework for the semantic retrieval of multimedia contents. Our framework is ontological knowledge base-driven in the sense that the interpretation process is integrated into a unified structure around a knowledge base, which is built on domain ontologies. Our framework also integrates such components as for knowledge base augmentation by user preference and context. We also present our prototype system we have been developing to test our framework ideas.**

***Keyword*—Knowledge Base, Ontology, Semantic Search, Smart TV**

I. Introduction

WE are witnessing the last few years rapid increasing of smart media such as smart phone, tablet PC and smart TV. Especially, smart TV equipped with a processor, large inexpensive disk storage, and high-speed Internet access is predicted to be an open home digital hub in the near future [1]. In the line of such movement, digital audiovisual content libraries and video on demand services are already making business in the market. Furthermore, the business will be expanded to the broadcasting contents by real-time program capturing and streaming capabilities [2].

Recently, the advanced technology of contents retrieval becomes a dominant factor for the success of such business [1,3,4]. For example, users want to easily search for contents regardless of the sources (i.e. repositories) such as digital contents libraries, VoD(Video on Demand) services, and broadcasting. Moreover, users expect that their preference and context such as favorite football player, favorite football team, the present football competition and major games of the competition are reflected in their search results spontaneously.

The above requirements can be satisfied in a system which stores semantic descriptions for the multimedia contents, user preferences, and contexts and provides semantic search capabilities on the semantic descriptions [1,3-8]. However, considering the requirements, we can see some features that the system should have. First, since there are many different content sources and metadata representation schemes, the semantic descriptions for the contents should be managed in a single repository (i.e. knowledge base) to support integrated semantic search. Second, the users should be able to express their information need as a simple keyword phrases, because ordinary users don't know the complex formal query language and the schema of the underlying knowledge base. Third, the knowledge of user preference and context having very dynamic trait should be represented in the same way with the knowledge of contents metadata and treated equally in order to reflect them automatically.

The input of the semantic search system is a keyword phrase and the final output is a list of contents matching with the keyword phrase reflecting user's intention. In this process the system has to interpret the keyword query to fill the gap between the keywords and the user's intention and has to find the metadata description in the knowledge base that accord with the interpretation [7-10]. The target contents are those connected to the identified metadata description. In other words, the process converts the keyword phrase into a formal query statement of the knowledge base. Due to the ambiguity of keyword phrase, there may be multiple formal queries produced from one keyword query. How to rank these queries is a big challenge[7].

In this paper, we describe a framework for semantic multimedia contents retrieval in smart TV. Our framework is

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ontological knowledge base-driven in the sense that the interpretation process is integrated into a unified structure around a knowledge base built on domain ontologies. Moreover, our framework allows the knowledge base augmentation with the dynamic context and user preference knowledge in a uniform manner. The main objectives of our framework are to provide enhanced retrieval performance and better user interfaces based on the ontological knowledge base. Our framework provides domain ontologies to represent logically the contents metadata, user preference, and context data. It also includes such components as for knowledge base augmentation, user query interpretation, and adjustment of the interpretation result.

This paper is structured as follows: In Section 2 we briefly explain the conceptual architecture and principal functional components of our framework as well as generic approaches for the functions. Then, the prototype system to verify our framework ideas is presented in Section 3. In Section 4 we describe an application of prototype system in smart TV environment. Section 5 outlines the related works. In Section 6 we provide the conclusions of our work and a brief description of our future works.

II. Framework Description

In this section we provide an outline of our framework for the semantic retrieval of multimedia contents in smart TV. The conceptual architecture of the framework is presented in Figure 1.

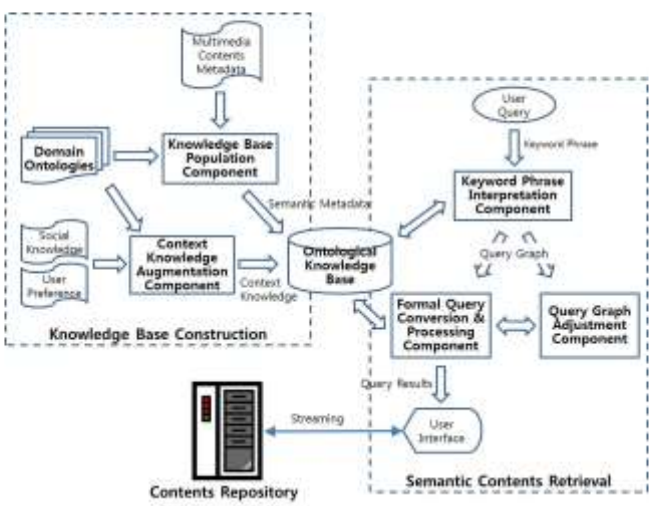


Fig. 1. Conceptual architecture of the framework

The framework has two sections. The first section relates to knowledge base construction, and the second one relates to semantic contents retrieval. The major functional components of the first section are domain ontologies, a knowledge base population component and a knowledge augmentation component. The second section has, as its major functional components, a keyword phrase interpretation component, a formal query conversion & processing component, and a query graph adjustment component.

As described in the figure, our framework is ontological knowledge base-driven as all the components provide their functions based on the knowledge base which is built on the domain ontologies. More specifically, the metadata of contents is represented in a logical graph in the knowledge base using the domain ontologies of such as movie, drama, and sports. The user preference and context data are also represented in the same way as the metadata of contents, and integrated in the knowledge graph. The user query (i.e. keyword phrase) is interpreted into a query graph by the keyword phrase interpretation component, and then a list of contents that accord with user's intention is returned by the formal query conversion & processing component. The keyword phrase interpretation is performed by picking up the most likely partial knowledge graph (called query graph) among candidate partial graphs that are extracted from the knowledge base. The candidate partial graphs are those that the user query could denote. Since the interpretation result is given as a graph, the user can easily adjust it to be fit for his/her intention in GUI.

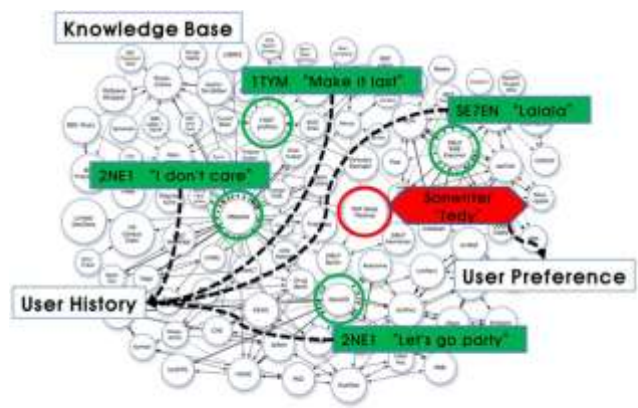


Fig. 2. User preference learning based on KB

Our approach for the knowledge augmentation with user preference is as follows. We can acquire the user preference knowledge through two ways. The first one is to get it from the user profile that user specified explicitly. The second one is to learn it from user's query history. Our approach for the user preference learning is distinct from general association rule mining, because our approach is also based on the knowledge base. In usual association rule mining, system mines only the gathered data for association rules. In our approach, the system mines whole knowledge base. That means the association rules are acquired not from the gathered query history but from the knowledge having been expanded through the knowledge graph. For example, consider the case that the history data about music video query which consists of singer (or group) name and music title is gathered (e.g., "2NE1, I don't care", "SE7EN, Lalala", "1TYM, Make it last", "2NE1, Let's go party"). We can map each element of the gathered data to knowledge entity so that we can expand the history data to the knowledge such as composer, genre and member of the music group. In the end we can find that the user's preference is for the composer "Tedy". Figure 2 shows the concept of our approach.

On the other hand, the social knowledge is acquired by applying text mining techniques to social media such as blog, news and bulletin board. For example, we can acquire the knowledge that the term, “Ronaldo Wink” relates to the quarterfinal match between Portugal and Germany in the World Cup Germany 2006 by analysing blogs and news. With the knowledge base being augmented by such knowledge, the system can give much more accurate query results to the user when the user enters the keyword phrase, “Ronaldo wink football video”.

The user query interpretation process in our approach, which is basically a graph-based technique like as other research [7-10], converts the keyword phrase into a partial knowledge graph of the knowledge base. A query graph can be easily translated into a SPARQL[11] statement, because SPARQL is a graph pattern based query language. The process consists of three steps: term mapping, query graph construction, query graph ranking. Term mapping maps the terms of the keyword phrase to the entities of the knowledge base. After that, query graph construction links the mapped entities so that the missing relations and concepts can be obtained and a complete query graph can be constructed. Finally, the query graph ranking estimates the most likely query graph that best accords with the user’s intention among all the candidate query graphs.

III. Prototype System

In this section we present the prototype system that has been developing to verify our framework idea, focusing on main components such as domain ontology, ontological knowledge base, and user query interpretation module.

A. *Movie Domain Ontology*

In order to evaluate our framework, we have designed an ontology for the description of movie contents using Web Ontology Language (OWL)[12]. Figure 3 shows a part of the ontology. In the left section of the figure you can see the hierarchy of classes and object property. You can see the description of LeadingActor class in the right section. In OWL, which is based on Description Logic (DL), classes are classified into two categories: primitive class and defined class. A primitive class has a necessary membership condition, while a defined class has a necessary and sufficient membership condition [12]. In the figure, defined classes are marked with triple line icon.

In our approach, the usage between primitive and defined class is distinguished strictly. Though OWL allows the ontology modellers to assert an individual to be an instance of multiple classes, we assert an individual to be an instance of one class. They are automatically asserted to be an instance of other classes afterwards by DL reasoning. For example, every individual that denotes a human being must be asserted to be an instance of Person class, and some of them having playLeadingRole property are asserted to be instances of LeadingActor class afterwards by DL reasoning engine. Such scheme means role concepts ought to be represented differently from type concepts. A role concept is a class, but, unlike a type class, its instances are not fixed [13]. For example, the instances of LeadingActor class continuously change, as new movies are added to the knowledge base or existing movies are removed. A role concept must be related to an event its instance participates in. The properties used in the necessary and sufficient membership condition of a defined class can be regarded as the events.

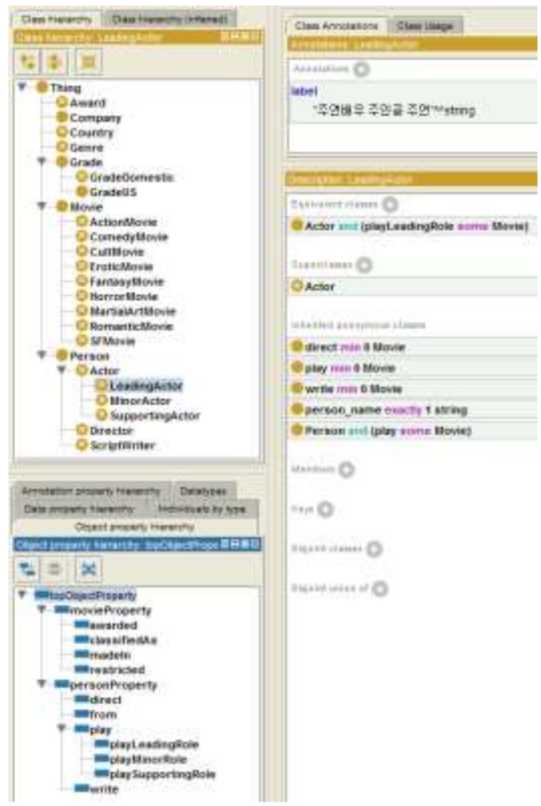


Fig. 3. Movie domain ontology

It is very difficult and troublesome to build a knowledge base from scratch. So an automated or semi-automated tool is needed to migrate contents metadata from a legacy database to the knowledge base. The above scheme makes the knowledge base population including migration very easy. For example, consider an individual denoting a movie content, Iron Man. Under the above scheme it is enough to assert the individual as an instance of Movie class and describe its properties. You don’t need to suffer from deciding which other classes the individual should be belonged to. The reasoning engine automatically asserts the individual as an instance of ActionMovie and SFMovie classes by using the described properties.

B. *Movie Contents Knowledge Base*

Figure 4 shows the knowledge base built using the movie domain ontology. In the middle section of the figure you can see the instances of ActionMovie class, while in the right section you can see the property description of movie_0002 individual. The individuals are automatically classified as instances of ActionMovie class by the DL reasoning engine.

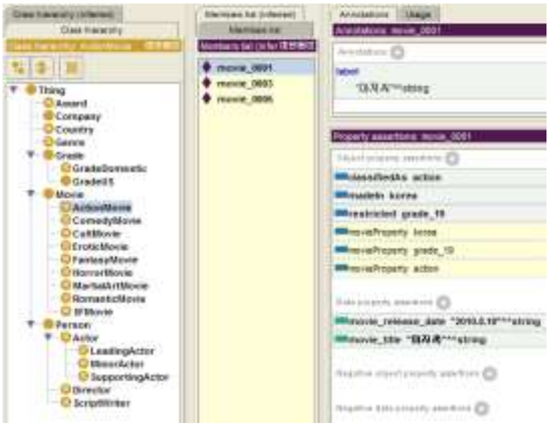


Fig. 4. Movie Contents Knowledge base

In our knowledge base, every entity has a label annotation as in upper-right section of the figure. Using such labels the system makes indexes of the entities and maps user keyword to the corresponding entities. Figure 5 shows the process for knowledge base indexing and user query interpretation.

C. User Query Interpretation

The keyword phrase interpretation component translates the user query into a partial knowledge graph (i.e. query graph). That process is carried out through three steps as in Figure 5: term mapping, query graph construction and query graph ranking.

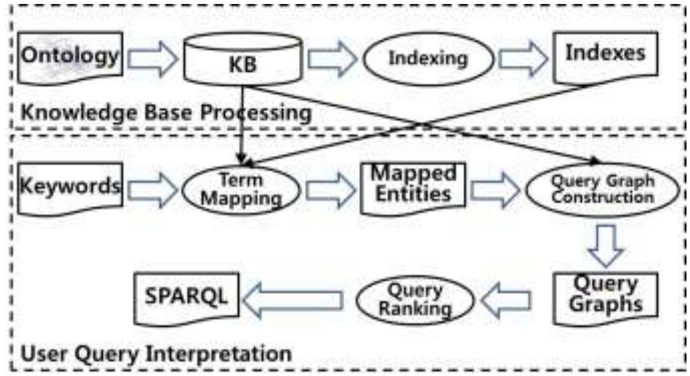


Fig. 5. KB processing & User Query Interpretation Process

Term Mapping

The purpose of term mapping is to find corresponding knowledge entities (i.e. classes, individuals, properties and literals) for each term in the keyword query. The name and labels of the entities are used for mapping. In our implementation, the term mapping process indexes the names and labels of knowledge entities, and using the fuzzy search feature of Lucene[14], returns a list of knowledge entities for each entered keyword. The returned entities are ranked according to syntactic similarity to the respective keyword.

```
USER_QUERY_INTERPRETATION(keyword_list)
   user_query_segment_mapping_list = TERM_MAPPING(keyword_list);
   initialize new empty query_graph;
   initialize new empty instance_entity_list;
   FOR mapping in user_query_segment_mapping_list
      add instance_entity_list to mapping;
      clear instance_entity_list;
      query_graph_store = CONSTRUCT_QUERY_GRAPH(mapping);
  extract shortest_query_graph containing all the knowledge_entities of mapping
        from query_graph_store;
      add shortest_query_graph to query_graph;
      IF mapping is not the last one
         THEN translate shortest_query_graph into SPARQL query statement;
               instance_entity_list = process SPARQL query with KB;
   RETURN query_graph;

TERM_MAPPING(kwyword_list)
   initialize new empty user_query_segment_mapping_list;
   FOR keyword in kwyword_list
      initialize new empty mapping_list;
      find knowledge_entity for keyword;
      add knowledge_entity to mapping_list;
      IF knowledge_entity is class entity
         THEN add mapping_list to user_query_segment_mapping_list;
   RETURN user_query_segment_mapping_list;

QUERY_GRAPH_CONSTRUCTION(mapping)
   initialize new empty query_graph_store;
   extract class_entity from mapping;
   FOR knowledge_entity (except class_entity) in mapping
      make connections between knowledge_entity and class_entity;
      add connections to query_graph_store;
   RETURN query_graph_store;
```

Fig. 6. User query interpretation algorithm

Query Graph Construction

The query graph construction process builds up candidate query graphs with the knowledge entities mapped in the term mapping step. The process explores all entities related to the mapped entities. The exploration simply incorporates all entities and literals within a pre-defined range (i.e. distance) and makes up the missing relations and concepts for the user query. From the explored paths, only those, called connections, are selected where the first and the last vertex correspond to one of the mapped entities. When the connections can be joined into a graph containing all the entities mapped in the term mapping step, the candidate query graph is generated according to the following rules: 1) Class entities mapped by the term mapping or discovered by the exploration are regarded as variable nodes. 2) Individual entities and literals are regarded as end nodes. 3) Property entities are regarded as the edges of the query graph.

Query Graph Ranking

After the term mapping and query graph construction, multiple candidate query graphs will be produced. There comes the problem: how to pick up the most appropriate query graph for the user? Various models have been suggested for the evaluation [7-10,15]. One of the simplest way is to give higher rank to the query graph that has the shorter path connecting all the mapped entities. We use the shorter path model because the assumption is generally valid that the knowledge entities which have conceptual relations are located close to each other in a knowledge graph [9].

The algorithm for the user query interpretation process is shown in Figure 6. In the algorithm we consider the case that a keyword is mapped to one entity. But actually it is not, so the multiple mapped entities should be split into different query sets. The query set split step is a process of enumerating all possible combinations from different senses of each keyword.

IV. Implementation of Prototype System

In this section we describe the implementation of prototype system on smart TV environment. There should be approximately 2,000 instances of content in ontological knowledge base. And they are an experimental metadata for the performance verification of prototype system. The user keyword phrase can be interpreted by prototype system in various ways. It is possible for smart TV environment to interpret the search intention of their keyword phrase and knowledge base. The interpreted user queries and search results of knowledge base can be used in combination with other contents searcher, such as VoD, Broadcast, and UCC(User Created Contents) searcher. The prototype system consists of three parts: the Knowledge Base Server, Content Retrieval Server, and Smart TV Client.

A. *Knowledge Base Server*

The knowledge base server enable contents retrieval server to perform exploration of knowledge base. The knowledge base consists of contents metadata about instances of movie, drama, entertainment, and music video.

The knowledge base server should be to create the index about entity-label. Then, it should be to recognize the entity for entered user keyword phrase. After that knowledge base server links the recognized entities so that query graph can be constructed. And the knowledge base server should be to rank candidate query graphs. At that time, it is to make use of the model of entities weight.

Knowledge Entity Indexing

The knowledge base server loads the contents metadata. The server is configured with an entity label and the URI(Uniform Resource Identifier) to generate the index. This index is used to recognize the knowledge entity to user keyword in the process of knowledge entity recognition. The creation of indexes in the implementation of the lucene library is used. The index is divided into a resource and literal.

Knowledge Entity Recognition

The purpose of Knowledge Entity Recognition is to find corresponding ontology entities, such as classes, individual, properties and literals. In our implementation, we are using Korean morphological analyzer. After the completion of stemming, find the best combination of keyword for entity recognition. Morphological Analyzer is a software library capable of detecting morphemes in a piece of keyword phrase. The Figure 7 describes the results of knowledge entity recognition from the best combination of keywords. The results of recognized entities have contained node URI and type information of node.

Fig. 7. Results of knowledge entity recognition

Query Graph Construction and Ranking

The knowledge base server builds up query combination from the recognized entities. The query combination process constructs candidate query graphs with the ontology resources mapped entities. The query graph ranking is to find the best query graph from candidate query graphs. Figure 8 shows the conceptual spanning tree of user query. Figure 9 shows an expanded ontological query graphs. It is expanded the query graph through the path of graph from the conceptual spanning tree. It is the best query graph.

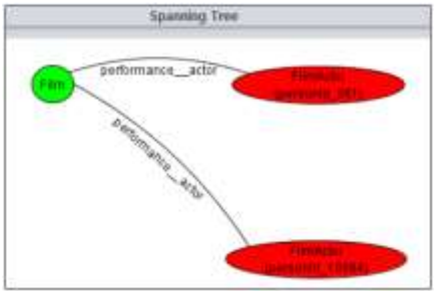


Fig. 8. Conceptual spanning tree of user query

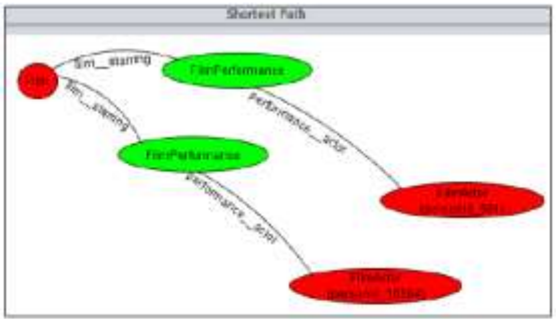
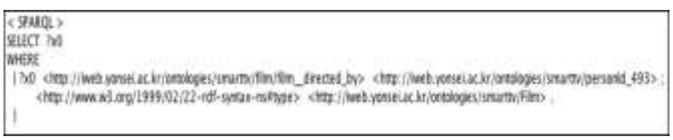


Fig. 9. Expanded ontological query graphs

Dynamic SPARQL Generation

The knowledge base server performs the dynamic SPARQL generation through the best query graph. Figure 10 shows an example of SPARQL query. In our implementation we are using Jena ARQ that is SPARQL processing engine.



```
< SPARQL >
SELECT ?x0
WHERE
{ ?x0 <http://web.yonsei.ac.kr/ontologies/smartv/film/film__directed_by> <http://web.yonsei.ac.kr/ontologies/smartv/persanId_493> ;
      <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://web.yonsei.ac.kr/ontologies/smartv/Film> .
}
```

Fig. 10. Example of SPARQL

B. Contents Retrieval Server

The contents retrieval server is passed the user entered keywords. And interpreted query is created by knowledge base server. The interpreted query is passed to the VoD Contents Searcher, Broadcast Contents Searcher, and UCC Contents Searcher. The search results are returned by the each searcher. Figure 11 shows the class diagram of contents retrieval server.

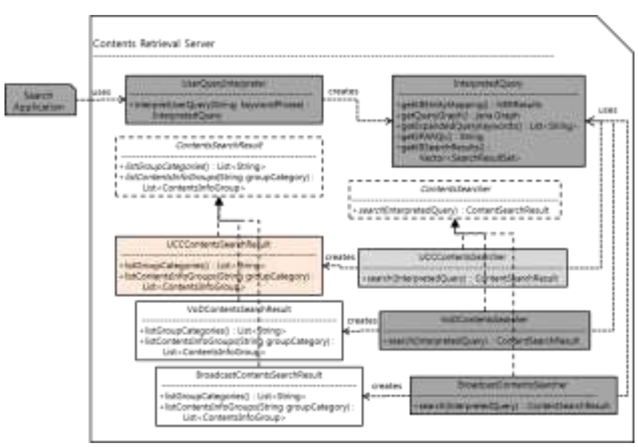


Fig. 11. Class diagram of contents retrieval server

User Query Interpreter

The user query interpreter creates an interpreted query via knowledge entity recognition, query graph construction and ranking, dynamic SPARQL generation and SPARQL processing results.

VoD Contents Searcher

The VoD Contents Searcher retrieves contents of VoD to provide streaming services in VoD contents repository. The search results are applied to the dynamic classification system.

Broadcast Contents Searcher

The Broadcast Contents Searcher retrieves contents of broadcast in EPG(Electronic Program Guide) database.

UCC Searcher

The UCC Searcher generates a query that is suitable for global repository, such as Youtube and Daum TV pot. The created query is a global repository input. And search results are completed post-processing, such as filtering, ranking, and grouping.

C. Smart TV Client

The smart TV client acquires the user entered keywords, and it is passed on to the contents retrieval server. The user query interpreter delivers the interpreted query for user feedback. Also, it provides the search results via filtering, ranking, and grouping.

Smart TV Search Interface

Figure 12 describes the GUI of smart TV client. The smart TV client consists of three parts: the preferred broadcast channels, information of preferred broadcast contents, and history of VoD contents. User entered keywords is passed to the contents retrieval server.

Fig. 12. Search interface in smart TV

Smart TV Search Results Interface

The search results interface provides two type of information. Firstly, the client provides search results to be filtered, ranked, and grouped. Second, it provides expanded keywords phrase for interpretation of user keyword. Figure 13 shows search results interface in smart TV.

Fig. 13. Search results interface in smart TV

Smart TV Recommendation Interface

Figure 14 shows recommendation interface for preferred broadcast contents. In order to provide more accurate program recommendation, we use not only the user watching history, but also the user program preference and program preference updated as a user preference profile by periods.

Fig. 14. Personalized video recommendation interface in smart TV

V. Related Works

Recently, digital audiovisual library systems, video on demand service systems are developed based on widely accepted standards for audiovisual content descriptions such as MPEG-7 [16] and TV-Anytime [2]. An MPEG-7 driven framework for managing semantic metadata for audiovisual content was presented in [1]. The framework allows the description of domain ontologies within MPEG-7 and the encoding of semantic multimedia metadata descriptions that utilize the domain ontologies in the Semantic DS of the MPEG-7 MDS.

On the other hand, translating keywords to formal queries is a line of research of information retrieval communities. [7] represents an attempt that specifically deals with keyword queries in semantic search engines. There, keywords are mapped to elements of triple patterns of predefined query templates. These templates fix the structure of the resulting queries a priori. These problems have been tackled recently by [8.9]. In [9], a more generic graph-based approach has been proposed to explore all possible connections between nodes that correspond to keywords in the query. This way, all interpretations that can be derived from the underlying knowledge graph can be computed.

With respect to these recent works, our approach is distinct in three aspects. First, we enrich the knowledge graph with user preference knowledge and context knowledge. Thus, the meanings of user query are interpreted more accurately. Second, our framework provides the principle for ontology design and knowledge base population so that contents' metadata can be easily migrated by the computer from legacy content libraries. Third, user can easily adjust the interpretation result of his/her keyword query in GUI, since the interpretation result is provided as a partial knowledge graph.

In Semantic Web, the semantic information of the Web is recorded by RDF triple and is embedded in Web pages. In RDF triple, the concepts and their relationships are defined. We call the data defining the resource and its relations (concept and property) metadata. Relations between concepts/instance are required to be explicitly stated in formal logic queries, which are often missing in keyword queries. OntoLook is a prototype relation-based search engine, which has been implemented in a virtual Semantic Web environment. The core idea of "OntoLook" is that there are relations among the submitted keywords, and Semantic Web offers the ability of processing relations at the system architecture level[17].

VI. Conclusion and Future Works

In this paper, we proposed an ontological knowledge base-driven framework for semantic multimedia contents retrieval. We briefly explained the conceptual architecture and principal components. We also explained generic approaches to implement each component. Our framework has the distinctive features that the knowledge of user preference and context is spontaneously reflected in the query process and that the interpretation of user query can be easily adjusted by the user in GUI. Such features stem from the fact that all the knowledge of content metadata, user preference and context is seamlessly represented in a single knowledge graph and that the interpretation result is also represented as a partial knowledge graph.

To verify our framework ideas we have been developing a prototype system. We discussed the domain ontology, i.e. movie ontology and some principles for ontology design and knowledge base construction. The principle is simple but very powerful when we can use Description Logic reasoning. We gave an illustration of the knowledge base which is built based on the movie ontology and showed an example of DL reasoning in use. The interpretation process of user query (i.e. keyword phrase) was explained and the algorithm for the process was provided.

Our prototype is not at the final version, but still developing. In the future we will implement the knowledge augmentation component and the query graph adjustment component. Especially, the user preference learning from user query history and the social knowledge mining would give distinctive features to our framework.

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A Proposal of Semantic Analysis based Integrated Multi-Level Search System for Smart TV

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***Abstract*—Aligned with the rapid change of broadcast environment TV is no longer than a passive device to receive a signal of terrestrial television broadcasting. A Smart TV is the new trend of integration of the Internet and Web 2.0 features into the modern television sets and set-top boxes. The users having much experience in a computer want to use a Smart TV alike. However, a Smart TV has yet to provide various user interface devices such as a mouse and a keyboard thus it is needed to develop new search technology to analyze user intents from simple user keyword phrase and search the target contents from the multiple sources including broadcast network and Internet. In this paper, we proposed the framework of semantic analysis based integrated multi-level search system to improve search accuracy and expand search coverage. The proposed system can retrieve the user desirable multimedia contents from various sources at a time by analyzing ambiguous user keywords phrase with ontological knowledge.**

***Index Terms*—Semantic Network, Multi-Level Search, Integrated Search, Smart TV**

I. INTRODUCTION

The Internet technology has evolved very fast over the past several decades, so it has been having a big effect on our daily life such as education, art, game, and broadcast etc. In reality, it is no exaggeration to say Internet is an indispensable infrastructure to lead everyday life these days. Now Internet technology plays a principle role in developing new technologies as well as becoming a fundamental infrastructure to provide various services. As the Internet has been growing up, many technologies have taken another big step forward to a new paradigm shift – the convergence with IT technology. The broadcast technology has also expanded its transmission infrastructure to Internet. TV is no longer than a passive device to receive a signal of terrestrial television broadcasting and now it is evolving into a smart device providing Internet based services [20]. Nowadays we can watch plenty of multimedia contents scattered over the Internet and make use of interactive services including SNS, Internet full browsing, and applications on Smart TV.

While the Smart TV provides multiple services in addition to broadcasting, the fact still remains the major role of TV is to watch multimedia contents either TV shows or payable videos. These days users can get a great deal of multimedia contents from various sources involving broadcasting stations or contents providers on Internet; however, it is quite difficult to find a multimedia content what a user wants to watch using the simple search keywords from the limited UI/UX on TV. We think a TV hasn't still been a good interactive multimedia device with easy input devices such as a mouse and a keyboard to get lots of input data easily from users but a fantastic appliance to watch video contents using a large screen. Therefore it is needed to develop a new search system for Smart TV retrieving target contents easily with ambiguous search keywords from various multimedia sources including broadcast network and Internet. We proposed the semantic analysis based integrated multi-level search system searching considering newly emerged requirements from broadcast environment changes. In the rest of this paper, we present our contributions. In Section II, we present the related works and Section III describes the proposed system, the semantic network based integrated multi-level search system. Then we discuss our current works and future works to improve multimedia search efficiency.

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II. RELATED WORKS

Unlike textual data, whose content can be searched for using text strings, multimedia information retrieval(MIR) is dependent on processes that have either cumbersome requirements for feature comparison (e.g. color or texture) or rely on associated, more easily processable descriptions, selecting aspects of an image or video and expressing them as text, or as concepts from a predefined vocabulary.[17]

The earliest years of MIR were frequently based on computer vision algorithms which focused on feature based similarity search over images, video, and audio. Influential and popular examples of these systems are QBIC [1] and Virage [2], around mid-90s. Within a few years, the basic concept of the similarity search was transferred to several Internet image search engines including Webseek [3] and Webseer [4]. Significant effort was also placed on the direct integration of the feature-based similarity search into enterprises-level databases such as Informix datablades, IBM DB2 Extenders, or Oracle Cartridges [5] to make MIR more accessible to private industry.

In the area of video retrieval, the main focus in the mid-90s was on robust shot boundary detection; the most common approaches involved thresholding the distance between color histograms corresponding to two consecutive frames in a video [1]. Hanjalic et al. [6] proposed a method which overcame the problem of subjective user thresholds. Their approach was not dependent on any manual parameters. It gave a set of key frames based on an objective model for the video information flow. Haas et al. [7] described a method of using the motion within the video to determine the shot boundary locations. Their method outperformed the histogram approaches of the period and also performed semantic classification of the video shots into categories such as zoom-in, zoom-out, pan, and so on. A more recent practitioner's guide to video transition detection is given by Lienhart [8].

Near the turn of the 21st century, researchers noticed that the feature-based similarity search algorithms were not as intuitive or user-friendly as they had expected. One could say that systems built by research scientists were essentially systems which could only be used effectively by scientists. The new direction was geared toward designing systems which would be user-friendly and could bring the vast multimedia knowledge from libraries, databases, and collections to the world. To do this, it was noted that the next evolution of systems would need to understand the semantics of a query, not simply the low-level underlying computational features [18]. This general problem was called "bridging the semantic gap". The semantic gap is the lack of coincidence between the information that one can extract from the visual data and the interpretation that the same data have for a user in a given situation. Techniques for attempting to bridge the semantic gap in multimedia retrieval are followings [19].

A. Automatic Annotation

The current techniques for auto-annotation generally fall into two categories; those that first segment images into regions, or 'blobs' and those that take a more scene-orientated approach, using global information.

Duygulu et al. [9] proposed a method by which a machine translation model was applied to translate between keyword annotations and a discrete vocabulary of clustered 'blobs'. Jeon et al. [10] improved on the results of Duygulu et al. [9] by recasting the problem as cross-lingual information retrieval and applying the Cross-Media Relevance Model (CMRM) to the annotation task. Lavrenko et al. [11] used the Continuous-space Relevance Model (CRM) to build continuous probability density functions to describe the process of generating blob features.

Most of the auto-annotation approaches described above performs annotations in a hard manner; that is, they explicitly apply some number of annotations to an image. A hard auto-annotator can cause problems in retrieval because it may inadvertently annotate with a similar, but wrong label.

B. Semantic Spaces

Instead of applying hard annotations, we have developed an approach in which annotation is performed implicitly in a soft manner. A semantic-space of documents (images) and terms (keywords) is created using a linear algebraic technique. Similar documents and/or terms within this semantic-space share similar positions within the space. Latent Semantic Indexing is a technique originally developed for textual information retrieval. Berry et al [12] described how Latent Semantic Indexing can be used for cross-language retrieval because it ignores both syntax and explicit semantics in the documents being indexed.

C. Semantic Annotation

Early work on semantically describing images using ontologies as a tool for annotating and searching images more intelligently was described by Schreiber et al [13]. Several authors have described efforts to move the MPEG-7 description of multimedia information closer to ontology languages such as RDF and OWL [14, 15].

The aim of using ontologies to describe multimedia resources is to provide well-structured information to improve the accuracy of retrieval. Semantic web technologies also facilitate the integration of heterogeneous information sources and formats. Well-structured information is crucial for providing advanced browsing and visualization facilities, as opposed to more traditional query-based systems.

There are several approaches to semantically annotating multimedia. The aceMedia project [16] is developing a knowledge infrastructure for multimedia analysis, which incorporates a visual description ontology and multimedia structure ontology. They have also developed the M-OntoMat-Annotizer tool that allows users to manually annotate multimedia items with semantic information. Won-Ken Yang at al [21] developed an image description and matching scheme using synthesized spatial and statistical features for recommendation service.

III. SEMANTIC MULTIMEDIA CONTENTS RETRIEVAL FRAMEWORK

The Smart TV has various multimedia content sources such as broadcasting stations and various content providers scattered on Internet. We classified these multimedia content sources into three categories. The first is the local repository managed by Smart TV businesses similar to IPTV businesses such as QOOK TV, B TV, and U+ TV. The second is the EPG (Electronic Programme Guide) repository managing the schedule information of TV program. The third is the global repository such as YouTube having plenty of UCCs.

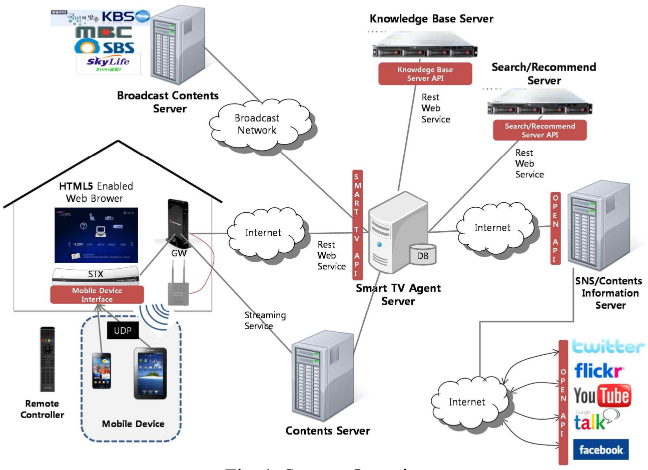

Fig. 1. System Overview

So we designed the semantic network based integrated multi-level search system with three search engines for local repository, EPG repository, and global repository. The proposed system overview is illustrated in Fig. 1. The Smart TV is connected by Internet with back-end search systems including Smart TV agent server, knowledge base server, search/recommend server, contents server, and SNS/contents information server and a user can interact with the Smart TV agent server through a HTML5 enabled web browser.

The Smart TV agent server performs the two-phase search process. In first phase, it analyses the meaning of user search keywords using the knowledge base server and then searches multimedia contents matching with the analyzed search keywords from several contents repositories in second phase. The details of the two-phase search process are followings:

Phase 1: Interpretation of User Keywords

1) The user search keywords phrase entered through the web-based smart TV browser are sent to the Smart TV agent server.
2) The Smart TV agent server parses the blank-separate user search keywords phrase into a list of terms and sends it to the knowledge base server.
3) The knowledge base server finds knowledge objects corresponding to each term from the smart TV agent server.
   a. If it finds several knowledge objects matching with one term, it chooses one with the highest weight.
   b. If it finds nothing, it returns null value to the smart TV agent server.
4) The knowledge base server generates candidate query graphs connecting all possible permutations of knowledge objects.
   a. If it gets dozens of candidate query graphs, it regards the shortest graph as the best result and selects the top-N-best graphs.
   b. It picks out knowledge objects from each best graph and then creates the list of expanded user keywords.
5) The knowledge base server sends the smart TV agent server the interpreted results of user search keyword involving user search keywords, knowledge objects, query graphs and expanded user keywords.

Phase 2: Contents Search

1) The Smart TV agent server sends the interpreted user query to the local repository search engine.
2) The local repository search engine creates a SPARQL query with the best query graph and executes it.
3) The local repository search engine performs grouping, sorting and classifying on the search result sets and appends them to the interpreted user query. It finally returns the interpreted user query to the Smart TV agent server.
4) The Smart TV agent server dispatches the interpreted results to two other search engines, EPG repository search engine and global repository search engine.
5) Each search engine creates query expressions using the interpreted results and contents list.
   a. The EPG repository search engine generates a MySQL query.
   b. The global repository search engine generates queries for web search engines (e.g. YouTube, Daum, Naver, etc.).
6) Two search engines send the Smart TV agent server the search results being grouped, sorted, and classified.
7) The Smart TV agent Server integrates the search results from each search engine and browses it to a user.

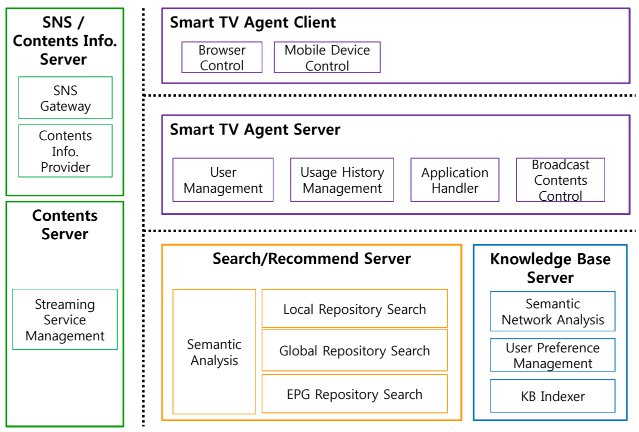

Fig. 2. System Architecture

Fig. 2 presents the architecture of the proposed system consisting of several subsystems. As it shown, each subsystem has several functional software blocks and has close relationship with other subsystems with various interfaces.

A. Smart TV Agent Server

The Smart TV agent server is designed to manage the user profile, watching history and user behavior pattern. It also controls the execution of Smart TV applications and broadcast contents. The functional blocks of the Smart TV agent server are as follows.

User Management

The Smart TV agent server manages user profiles containing user personal information. Some properties representing user preferences involving the favorite genre of movie, TV show, and music are stored in the knowledge base server and used for grouping, sorting, and classifying the search results. The TABLE I describes the data structure of user profile.

TABLE I
USER PROFILE

Name	Type	Description
seq_no	Integer	Sequential number
u_name	String	User name
u_id	String	User id
u_passwd	String	User password
u_sex	String	User sex
u_age	String	User age
u_job	String	User affiliation
f_movie	String[]	Favourite movie genre
f_show	String[]	Favourite TV program genre
f_music	String[]	Favourite music genre
s_id	String[]	User id for SNS
s_passwd	String[]	User password for SNS

User History Management

The Smart TV agent server gets the user's watching history from the Smart TV agent client and stores in the user history database. It conducts the regular time-frequency analysis of user histories collected during a specific period to derive user preference data such as the favorite TV channel, the favorite TV show and the latest watched video from the user history database. It stores the analyzed data in the knowledge base and creates the personalized menu page providing the current TV show on the favorite channel and the current channel list airing the favorite TV show by searching the EPG data with the user preference data.

Broadcast Contents Control

The Smart TV agent server controls broadcast contents and sets the DVR alarm by user request. It delivers user requests to a TV tuner card and changes the channel of terrestrial TV broadcasting and also provides the video recording facility setting it up in user-specified time.

Application Handler

The Smart TV agent server takes charge in handling various applications including a multimedia contents search application so it manages the life cycle of applications and handling the events from users and those applications.

B. Knowledge Base Server

The knowledge base server manages ontology representing metadata of multimedia contents retained in a contents server. We chose five areas of multimedia contents such as movie, soap opera, entertainment show, sports game and music video to implement domain ontology and designed an ontology using the Web Ontology Language (OWL). Fig. 3 shows the examples of film domain ontology. The left section describes the hierarchy of classes and object properties belonged to the film domain. The right section illustrates the description and instances of the Film class. For example, the Film class is a sub class of FilmDomain, Topic and Media class and it has dozens of object properties involving film_country, film_directed_by, film_distributors, and so on.

It is very cumbersome to set up a knowledge base from scratch, so we used a semi-automated tool to migrate contents metadata from a legacy database to the knowledge base server.

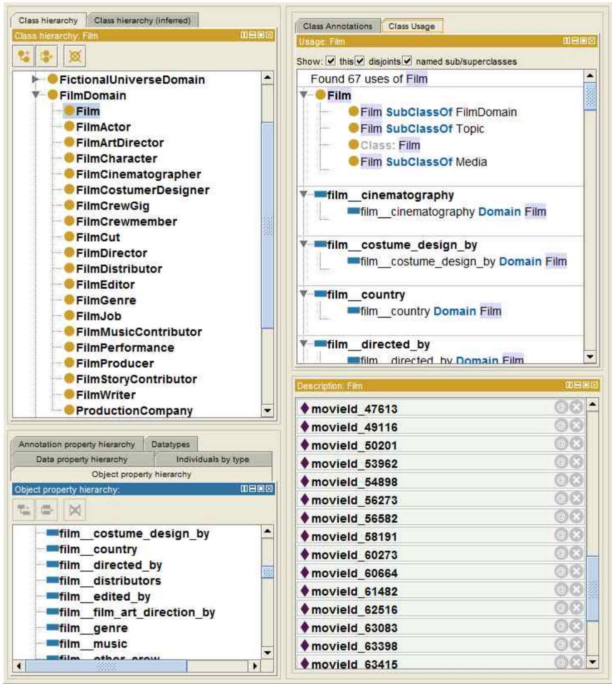

Fig. 3. Examples of the film domain ontology

The functional blocks of the knowledge base server are as follows.

Semantic Network Analysis

The Sematic Network Analysis module analyses the user search keyword referring to ontological knowledge and creates the interpreted user query including analyzing results such as knowledge objects, query graphs and expanded user keywords.

Fig. 4 depicts the interpretation process of user search keywords consisting of keyword phrase stemming, term mapping, query graph constructing and query graph ranking.

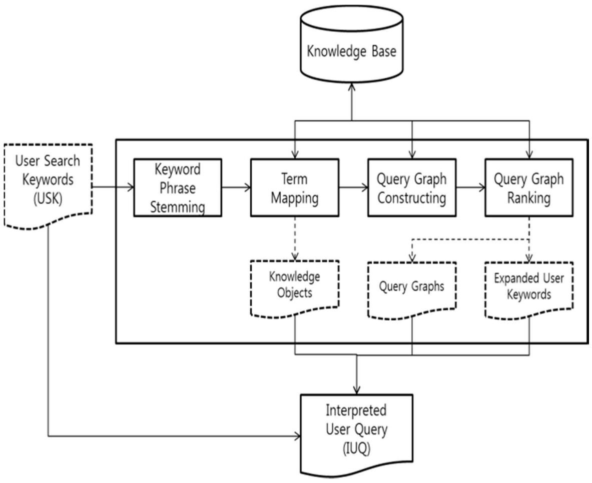

Fig. 4. Interpretation Process of User Search Keywords

- Keyword phrase stemming: it gets the blank-separated user search keywords from the search/recommend server and parses it into a list of terms. In this step, we don't consider the morphological analysis of user query since we assumes the user inputs a query expression form of not natural language but simple keywords.
- Term mapping: the knowledge base server makes indexes of itself with the name and labels of all knowledge objects when it starts up. It finds all knowledge objects corresponding to each term of user search keyword by comparing with the indexes of knowledge base. Sometimes it can have the ambiguity problem having several similar knowledge objects for one term. We ranked the knowledge objects by their pre-defined weight values and chose the highest one.
- Query graph constructing: it builds candidate query graphs connecting all possible permutations of knowledge objects within a pre-defined range (i.e. distance) with no duplicates. It can find new intermediate knowledge objects between user search keywords during query graph generation and make up the query graph including them.
- Query graph ranking: it sorts the candidate query graphs by their ranking points. We assume the closer together knowledge objects are, the stronger the semantic relationship between them, so we choose to use the shortest path model and give higher rank to the shorter query graph than others. After all we select top-N-best query graphs and make the list of expanded user keywords by extracting the labels of knowledge objects having the 'isDummy' value set to zero from those selected query graphs. When we design the ontology, we pre-annotated the knowledge objects being used for user search keywords by setting the 'isDummy' value to zero.

Fig. 5 shows the list of expanded words for the user search keywords, "Seung-Wan Ryu Movie". The knowledge base server makes it from query graphs connecting two knowledge objects, the movie director named Seung-Wan Ryu and the movie.

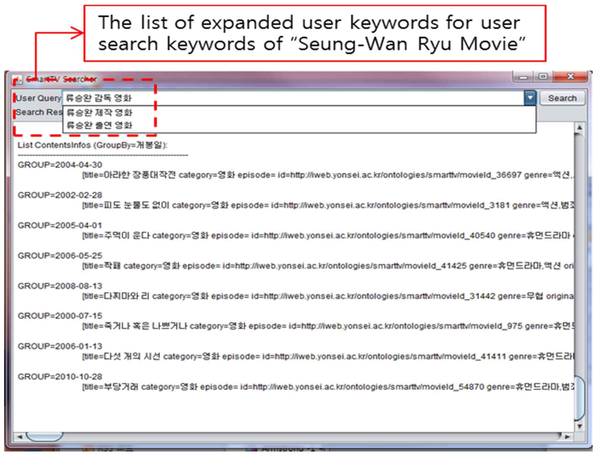

Fig. 5. Examples of the list of expanded user keywords

User Preference Management

The knowledge base server manages user preference data including favorite genre of movie, music, TV show, and favorite actor/actress to be used for grouping, sorting, and classifying the search results. Most of user preference knowledge comes from the user profile information and some of that could be achieved through analysis of user behavior pattern from the Smart TV agent server.

KB indexer

The knowledge base server creates indexes of itself with the name and label of all knowledge objects to ensure efficient performance and updates it periodically to reflect changes of ontology.

C. Search/Recommend Server

The search/recommend server provides three search engines with the interpreted user query arose from the semantic analysis of user search keywords and then searches multimedia contents matching with the interpreted user keywords from several repositories.

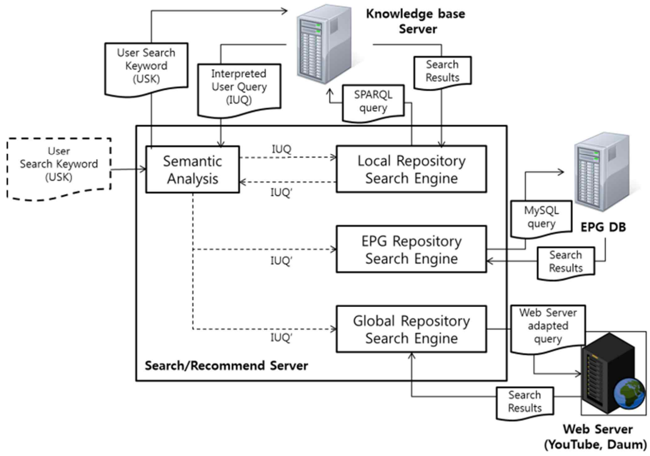

Fig. 6. Search Processing of the Search/Recommend Server

Fig. 6 depicts the searching steps of the search/recommend server. The search/recommend server gets the interpreted user query corresponding to the user search keyword from the knowledge base server and then sends it to the local repository search engine module at first. It receives the interpreted user query appending the search result from the local repository engine module and dispatches it other two search engine modules. After all it integrates all search results from three search engines and sends them to the Smart TV agent server. The functional blocks of the search/recommend server are as follows.

Semantic Analysis

The semantic analysis module gets the user search keywords from the Smart TV agent server and creates the interpreted user query involving user search keywords, knowledge objects, query graphs and expanded user keywords using the semantic analysis based on the ontological knowledge base. It delivers the interpreted user query to three search engines creating suitable forms of query expressions for respective repositories.

Local Repository Search Engine

The local repository search engine module is designed to search multimedia contents matching with the user search keywords in the local repository. First of all it creates a SPARQL query expression with the best query graph of interpreted user query and then executes it to search knowledge objects meeting the conditions represented in the where clause. When it gets the search results it performs grouping, sorting and classifying on them reflecting user preferences. It appends the search result sets, the contents list, to the interpreted user query and sends it to the Smart TV agent server.

EPG Repository Search Engine

The EPG repository search engine module aims to search the broadcast schedule information of target contents in the EPG repository retaining the weekly TV schedule including the four major public TVs and several cable TVs.

TABLE II
EPG DATA STRUCTURE

Name	Type	Description
key	String	Identifier
Channel	String	Channel number
Chname	String	Channel name
Program Title	String	TV show title
subtitle	String	TV show subtitle
StartTime	String	Start time of TV show
endTime	String	End time of TV show
Day	String	Broadcast day of TV show
Synopsis	String	Synopsis of TV show
Summary	String	Summary of TV show
genre	String	Genre of TV show
episodeNumber	String	Episode number of TV series
Directors	List<String>	List of directors
castMembers	List<String>	List of cast members
Uuid	String	Unique identifier of knowledge object
imgUrl	String	URL of TV show poster

It creates a MySQL query expressions with the contents list of interpreted user query and runs it to search the broadcast schedule of the contents list for the next three days. It sorts the search results by start time of TV show and sends them to the Smart TV agent server. The TABLE II shows the data structure of EPG.

Global Repository Search Engine

The global repository search engine module seeks to filter out undesirable search results from web search engines. It creates queries adapted for the two web search engines including YouTube and Daum TV pot with the contents list of interpreted user query and then dispatches queries to them. The respective web search engine searches the UCC (User Created Contents) matching the contents title with the contents list of interpreted user query and then returns them to the global repository search engine.

The global repository search engine conducts following three steps:

- Filtering: It uses the simple term frequency (TF) to filter out unsuitable contents from the search results. It builds the keyword list for each UCC by collecting the tags and tokenized words of content title and then calculates similarity between the keyword list of each UCC and the user search keywords. After performing on all contents it picked out contents having similarity over a specific threshold. We set the threshold value of threshold to 0.3 by experiment results. The following simple expression can be used to estimate a similarity $S(q, c_i)$ of a content item c_i and user query q :

$$S(q, c_i) = n(q \cap c_{i\in N})/n(q \cup c_{i\in N}) \quad (1)$$

  where

  c_i = word list of content item i;
  q = word list of user query .

- Re-ranking: It conducts re-ranking on the filtered results regarding user query, user preferences and similarity between contents. The following expression can be used to calculate rank point r_i of a content item c_i, user query q and user preference p :

$$S(c_i, c_j) = n(c_{i\in N} \cap c_{j\in N})/n(c_{i\in N} \cup c_{j\in N}) \quad (2)$$

$$S(c_i) = \sum_{j=1}^{n} S(c_{i\in N,} c_j) \quad (3)$$

$$S'(c_i) = \frac{S(c_{i\in N})}{\mathrm{M\,ax}\,S(C)} \quad (0 \le S'(c_i) \le 1) \quad (4)$$

$$S(p, c_i) = n(p \cap c_{i\in N})/n(p \cup c_{i\in N}) \quad (5)$$

$$r_i = \alpha \cdot S(q, c_{i\in N}) + \beta \cdot S'(c_{i\in N}) + \gamma \cdot S(p, c_{i\in N}) \quad (6)$$

  where

  c_i, c_j = word list of content item i, j ;
  q = word list of user query;
  p = word list of user preference .

In Equation (6), we use the term frequency to estimate all those similarities and set the weight value of α, β and γ to 0.55, 0.35, and 0.1 in succession by experiment results.

- Grouping: It puts the re-ranked results into several groups by contents providers, pre-defined categories and topics. We use content tags to classify them by content providers or categories and applies K-means algorithm to group them by similar topic cluster.

D. *Smart TV Agent Client*

The Smart TV agent client provides a user with web-based interactive user interfaces updating web pages responding to user commands. We think the current remote controllers aren't suitable for interactive user interfaces so we come up with the remote control application executing on the mobile device. The users can handle the Smart TV with the mobile device leaning back in couch. It receives the signal of mobile devices facilitating control of user interfaces using a UDP server and delivers it to the Smart TV agent server.

The Smart TV agent client obtains the user input data from the Smart TV browser and sends the Smart TV agent server those data to be used for creating new web pages. The users can enter various commands through the Smart TV browser; besides they should get some information from the Smart TV agent server occasionally. For example, they are allowed to receive the alarm message set up at specific time for their favorite TV show while they are watching other TV show. We designed to receive information from the Smart TV agent server using WebSocket within a browser.

E. *SNS/Contents Information Server*

The SNS/Contents information server plays a principle role in managing the contents information and social network services. It manages the detail information of a multimedia content like poster, synopsis, director, and actor/actress etc. The Smart TV agent server browses the detail information of the content user chooses to watch. It provides users with facilities utilizing the social network services such as Facebook and Twitter to share opinions about multimedia contents while watching a Smart TV. We build an automatic log-in system for registered users having the account information of social network services in their profiles.

F. *Contents Server*

The contents server takes charge of the seamless multimedia streaming service for the target contents - play, stop, fast forward, and rewind. It takes over the URL of multimedia content as search results or user command from the Smart TV agent Server and plays it after being clicked for watching on the Smart TV browser. It is very important to manage the unique URL for each multimedia content keeping consistency with the knowledge base server since it only recognizes the multimedia content by its URL.

IV. PROTOTYPE SYSTEM

We have developed the prototype system to verify our idea searching multimedia contents from various repositories based on the semantic analysis. We first built up the knowledge base server having over 2,000 multimedia contents of five domains including movie, soap opera, TV show, sports, and music video consisting of 10,000 knowledge objects designed by the ontological schema. Our prototype system has three subsystems involving the Smart TV client system, the Smart TV agent server system, and the contents server system. The Smart TV client system contains the Smart TV agent client and the Smart TV browser supporting HTML5. The Smart TV server system includes the search/recommend server, the knowledge base server, and the smart TV agent server.

The prototype system provides the integrated search results merging the respective search results from three search engines including the local repository search engine, the EPG repository search engine, and the global repository search engine for a user search request.

Fig. 7. The search results of local repository engine

Fig. 7 depicts the list of VoD contents from the local repository search engine. It listed search results for the best interpretation result stemming from the semantic analysis for the user search keyword "Seung-Wan Ryu, Movie". It gives the user the top-N-best interpretation results the user to select one of other interpretation results as the alternative search keywords when the user's not being satisfied with the best one located on the top of the list.

Fig. 8. The search results of EPG repository search engine

Fig. 8 shows the examples of EPG data matching with the user search keywords grouped by channel, broadcast day, and genre from the EPG repository search engine. The user can watch TV show immediately by choosing one or set up alarm to reserve the particular TV show not being on air now.

Fig. 9 represents the list of UCCs from two web search engines involving YouTube and Daum TV pot. We think we are not allowed to control the searching process of those web search engines so we designed the global repository search engine to focus on making the proper query expression and picking up the desirable results. The prototype system gets the search results from the web search engines and filters out the undesired results having low similarities with the user query and classified by the content providers, categories, and topics. The two preceding grouping factors described in the tag information of UCC are static, while the last factor is dynamic. We pick up the frequently used topic words from the description of UCC and then use the K-means algorithm to classify them in similar topic group.

Fig. 9. The search results of global repository search engine

V. CONCLUSIONS

As the Internet technology has been growing up fast, the broadcast environment has been expanded to Internet. Aligned with these trends TV is no longer than a passive device only to receive a signal of terrestrial television broadcasting and it is evolving into a smart device providing Internet based services like a smart phone. A Smart TV is the new trend of integration of the Internet and Web 2.0 features into the modern television sets and set-top boxes. The users having much experience in a computer want to use a Smart TV alike. However, a Smart TV has yet to provide various user interface devices such as a mouse and a keyboard thus it is needed to develop new search technology to analyze user intents from simple user search keywords and search the target contents from multiple sources including broadcast network and Internet.

In this paper, we proposed the framework of semantic analysis based integrated multi-level search system to improve search accuracy and expand search coverage. The proposed system can retrieve the user desirable multimedia contents from various sources at a time by analyzing ambiguous user keywords phrase with ontological knowledge base. We hope that the proposed system will foster the vision of user centered search system to understand user's intent from limited search keywords for beyond Smart TV.

In the future we will implement the knowledge augmentation component and the query graph adjustment component. Especially, the user preference learning from user query history and the social knowledge mining could be other distinctive features of our framework.

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