# IoT-RFID Testbed for Supporting Traffic Light Control

N. Choosri, Y. Park, S. Grudpan, P. Chuarjedton, and A. Ongvisesphaiboon

*Abstract*—**The paper investigates a prototype development of Internet of Things (IoT) application for traffic management. The retrofitted traffic light control solution is proposed and developed to support decision making of police officers. The system can figure out the congestion level of each road at a specific intersection with the help of RFID technology. The intention is to enhance sequencing and timing of traffic lights. A copy of information is also concurrently sent to the neighbours to support decision making at adjacent sites as well. Another feature of the system is the ability to track vehicles that are involved in crimes as well as illegal vehicles. The testbed prototype has been built successfully as a proof-of-the concept, to which more complicated features and further experiments can be applied.**

*Index Terms*—**Internet of things, RFID, traffic light control, traffic management, testbed.**

## I. Introduction

Traffic congestion is a very common problem in large cities and traffic lights are typically used to control the flow of vehicles at intersections. Neither manual control by police officers nor using predefined timers has been proven effective, but they are still being used in many places. Without taking an account of real-time traffic data for consideration, it can happen that a ‘green light’ is granted to an empty lane while a lot of cars are lined up at a ‘red light’ on the other lanes because the same time interval of green lights are granted to every lane. Radio Frequency Identification (RFID) is a competitive technology for identifying, tracing, and counting real-life objects and in the same vein plays a key role in a research paradigm of IoT. The RFID technology has been used in many domains, and traffic management is one of those. Even though, there are a number of alternative technologies that are applicable to traffic management systems, [1] argues using non-RFID technologies has significant drawbacks such as erroneous image processing in jam-packed situations or line-of-sight issues in using sensor-based devices. The literatures discuss the application of RFID technologies to solve traffic management problems. [2] investigates the using of RFID technology to collect three traffic parameters which are an average speed of vehicle, average waiting time, and queue size to input Neural Network model to determine the percentage of green time and duration of its cycle for the best throughput. [3] proposes a system that can estimate the congestion level from vehicle speed. The system is also capable of tracing vehicle information to fire the predefined rule in response to certain actions. For instance, if a vehicle is identified as a stolen car, the system identifies that vehicle on the map. [1] focuses on the study of generating dynamic sequence of traffic lights in order to improve a waiting time where RFID is used to capture the time-stamp of a vehicle at a certain location, while [4] investigates the practical aspect of using RFID system in collecting traffic information. The study explores the optimal points to install RFID readers to collect traffic information. In terms of the functions of the system, our research is the most similar to the work in [3]. However, the focus of this research is to put the concern on applying an Internet of Things (IoT) paradigm to solv more practical operation requirements for human-oriented traffic control. Simply put, IoT is a kind of system that enables objects to communicate with other objects for certain purposes. In this research, the ‘things’ that communicate together are traffic lights. One traffic light communicates to its neighbours to report traffic situations. Police officers who are in charge of controlling signals can use that information for better sequencing signals at that junction. The paper contributes the experiences of implementing a laboratory- testbed system for traffic control and shares the insights and lessons learned on what needs to be implemented and investigated to deploy the system for real usage.

The remaining of the paper is organized as follows: Section II reviews the concept of IoT. Section III describes the problem definition in terms of specification requirements. Section IV explains the system architecture, Section V discusses prototype implementation and experiment setup, Section VI outlines research paths for future work, and finally Section VII concludes the paper.

## II. Internet of Things

IoT is an emerging research paradigm and apparently the discovery of its body of knowledge is still in an infancy stage. So, the exact definition, architecture , scope, and standard are still not concretely defined and many literatures on IoT have been published from the survey of [5]. However, most scholars agrees on the idea of expanding and interpreting the pioneering conceptual definition of Kevin Ashton who defined IoT as “a standardized way for computer to understand the real world” [6]. With a key feature to create a smart environment together with quick response to support certain decisions and/or operations of human, IoT-based systems have been proposed in several applications such as supporting disabilities [7], managing diabetes therapy [8], building smart home [9], improving safety in mining operations [10], and using IoT for an intelligent transportation platform [11]. The term IoT has a strong relationship and is sometimes interchangeably used with a Ubiquitous Computing (or Ubicomp). The slightly different is that Ubicomb does not necessary require the internet

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connection to enable communication among objects [12]. It is used rather in a broader sense for defining smart ecology than IoT. For example, applying sensor technology to capture data to make a certain response is Ubicomp but not IoT. The simple equation to describe IoT is [12].

IoT= Physical Object + Controller,Sensor,Actuators +Internet

From the equation above, the Internet of Things can be compared to the communication of human. For instance, human have biological sensors such as ears, eyes, skin, taste buds, etc. to perceive what is happening in their surroundings. Human use body parts to make and receive sounds and require a name to enable others to get an attention. Communication can only succeed when the communication medium exists e.g. telephony network, mobile network, air. In order to let things carry the property similar to human's, sensors need to be attached to physical objects being considered. Objects, both sender and receiver, must have names, and digital communication is required as depicted in Fig. 1.

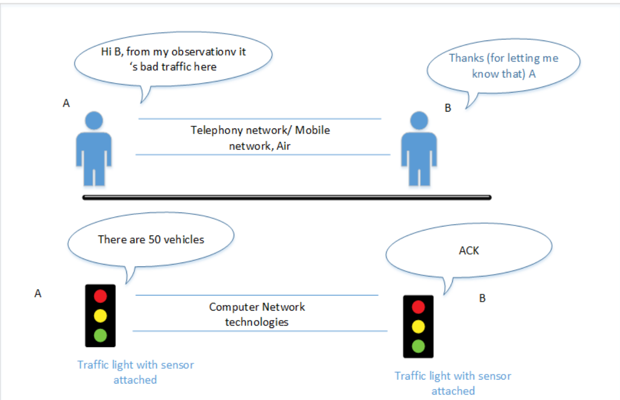


Fig. 1. A communication between things imitated human communication.

This paper focuses on the communication between traffic lights and RFID technology is applied to traffic lights for them to act as an *'eye'* to count identified tags, i.e. vehicles. The communication is established by a socket programming over Wi-Fi connection, so ports are like '*mouth'* and '*ear'* of sender and receiver consecutively. Traffic lights 'name' each other by calling RFID Reader name. One of the contributions of IoT to human operations in this scenario is that it can replace human in doing tedious exhaustive work. For example, traffic data can be collected and sent out persistently, which is nearly impossible when manual communication is applied.

## III. System Specification

Traffic management in many places including Thailand still relies heavily on physical operations of police officers. To control traffic lights, both manual and semi-automatic controls are practically in use. Manual control is a routine where police officers control the sequence of signals by observing the traffic situation usually from a police box located near the intersection. Semi-automatic approach, on the other hand, uses a predefined timer to control traffic. Police officers sometimes have to intervene traffic for some other routine operations. For example, they have to close some of the lanes occasionally in order to detect vehicles that violate traffic regulations i.e. motor tax expired or are involved in crimes, which slow down the flow of traffic causing serious congestion as depicted in Fig. 2.

Fig. 2. Manual inspections of police officers.

From the aforementioned real-life operations, this research aims to propose the solution that can improve current operations of the identified issues. The proposed solution is targeted at retrofitting the technologies i.e. RFID and IoT to fit them into the current operations instead of entirely changing the way the system operates. The specifications of the proposed system are identified as follows:

Specification 1: The system shall be able to figure out the congestion level at intersections to avoid impractical sequencing of traffic lights. For example, lanes that significantly congest than the others shall have longer green time and green light shall not be granted to empty lanes.

Specification 2: On top of the specification 1, the system shall also allow a police officer to receive information about adjacent junctions to support decision making that takes an account of accumulation effect.

Specification 3: Intervention of police officers to traffic flow (e.g. checking expiry of motor tax or insurance or vehicles involved in criminal cases) shall be reduced.

Specification 4: The system shall facilitate tracking vehicles that might be involved in crimes.

## IV. System Architecture

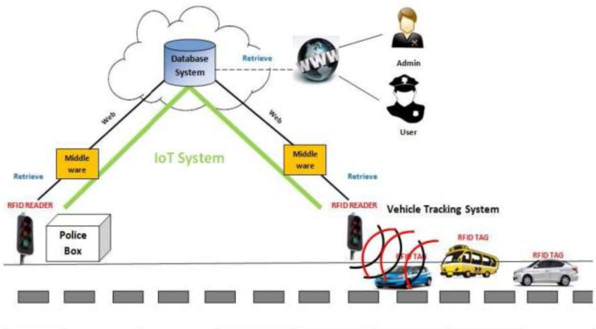


Fig. 3. System architecture.

Fig. 3 shows the overview of the proposed system. The system employs UHF Passive RFID technology to collect vehicle information. The prerequisite of the new system is that every vehicle shall carry an RFID tag, so that it can be identified by the RFID Reader. Tags are required to register to the system beforehand to allow vehicles to be tracked. A uni-directional RFID reader shall be installed at the intersection where a local middleware is synchronized to read tags when the tags are within the operating distance of the reader. The middleware also works with the database on server through Wi-Fi technology. With this configuration, the reader can count the number of identified tags to figure out congestion level. Also vehicles can be tracked and audited when required. This can help reduce the manual operations and traffic intervention of police officers when they have to check the expiry of motor tax and insurance. Moreover, the system can assist police officers tracing down vehicles that are involved in crimes. When a crime is notified with its associated vehicle information (e.g. license plate number, model, brand), a recent location of the vehicle can be tracked, and further actions can be taken i.e. extending the duration of red light to stop vehicles at certain intersections. One of the most significant features of the proposed system is that the feature is implemented based on IoT principle. Traffic information at each intersection is transmitted automatically to its adjacent junctions to provide further information to police officers for more effective decisions.

## V. Testbed Prototype

The testbed prototype is developed for a proof-of-concept. The following discusses the software and database that are developed for the system and the experiment set up used for verifying the configuration.

### A. Software System

There are two software applications operating the system. Both of them are Java-based applications developed to control the RFID reader for different purposes. These applications are associated with a centralised database for storing/retrieving traffic information.

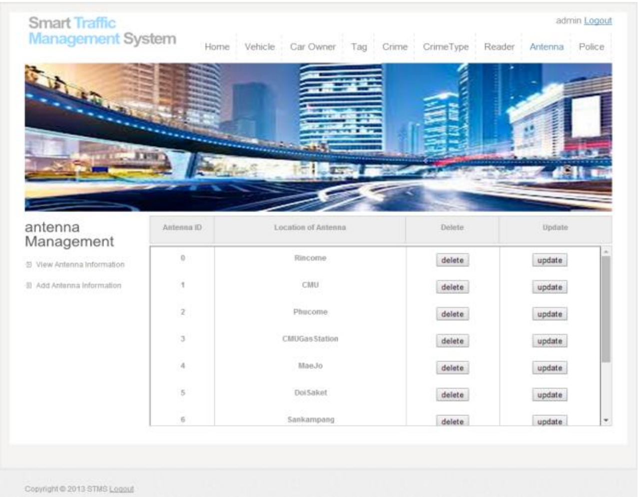


Fig. 4. Web base application screenshot.

#### 1) Web-based application

The main features of this application are as follows: 1) Tag administration i.e. registering a tag for a new vehicle, 2) Enabling police officers to view real-time traffic condition, 3) Allowing authorised users to enter information about criminal cases, for example, a crime reported by a witness and to track the recent position of a vehicle, and 4) Managing RFID Readers i.e. registering a new RFID reader for a new location. The example screenshot of the web based application for adding a new reader device to the system is shown as Fig. 4.

#### 2) IoT-based application

This application is a local-based application run by police officers at intersections, which receives the information from the Reader and displays it for the officers so that they can make better decisions on how to control the traffic lights. The key function of the application is to continuously search and read tags, in a certain time interval, within the operational distance of the RFID reader incorporated into traffic control. Traffic congestion information is extracted to support police officers for deciding an appropriate interval and sequence of 'red & green' time. The application also concurrently sends traffic information of one intersection to its neighbour intersections. The example screenshot in Fig. 5 shows the information collected at each intersection.

| Location | Plates No. | Car Brand | Model | Car Owner ID | Car Owner Name | Crime | Tax Expired | Time |
|---|---|---|---|---|---|---|---|---|
| CAMT | XO019 | Honda | Civic | 1509901115770 | Name 5 | N/A | Yes | 2014-06-04 14:46:00.0 |
| CAMT | NC876 | Nissan | CX9 | 1509901115896 | Name 1 | Forgery | No | 2014-06-04 14:46:00.0 |
| CAMT | KK555 | Toyota | Camry | 1509901115899 | Name 4 | Identity Thief | No | 2014-06-04 14:46:00.0 |
| CAMT | HA555 | Ford | March | 1509901115896 | Name 1 | N/A | Yes | 2014-06-04 14:46:00.0 |
| CAMT | KK555 | Toyota | Camry | 1509901115899 | Name 4 | Identity Thief | No | 2014-06-04 14:45:00.0 |

Fig. 5. The information collected at each intersection.

#### 3) Database

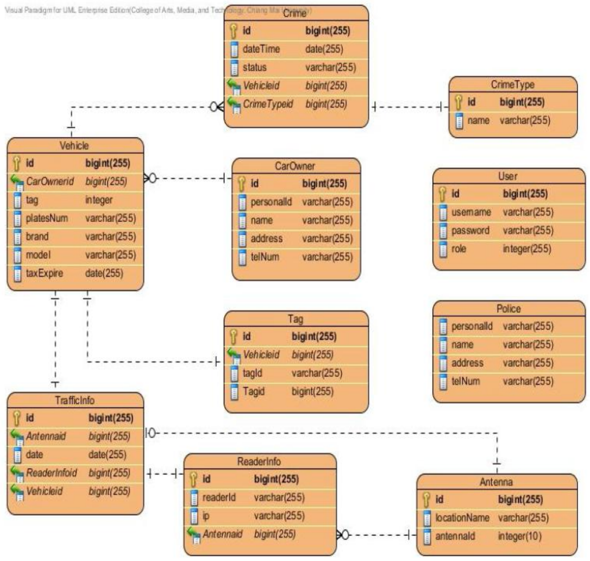


Fig. 6. Database design of the system.

The database is deployed in MySQL where the Tag ID is associated with other vehicular attributes to make a vehicle traceable for its owner information, expiration of tax, criminal case, if any, tracking information (i.e. the locations where the vehicle was detected) and associated Reader information etc. Not all data is accessible by every type of users. And some data can be viewed only after the user is authorized. For instance, tag registration and vehicle registration require administrator level while any registered police officer can view crime and vehicle information. The design of the database is shown in Fig. 6.

While MySQL is used to implement the testbed system, the system should be able to migrate to other Database Management Systems (DBMS) to provide more secure and reliable services and make the system scalable to accommodate a larger set of traffic data.

### *B. Demonstration Set up*

The specification of RFID readers using in this testbed system is a reader operated at passive Ultra Height Frequency (UHF), which means tags used in this system require no-battery. Tags have been measured for their maximum reading distance, and the result shows that they can support the reading distance of approximately 9 metres. With the geographical constraints of this research, however, the testbed evaluation and experiment of the study was conducted in an indoor-environment. The reader used in the testbed is a compact reader, which is equipped with antennas and a reader in one package. It is noted that typical RFID readers do not come with embedded antennas, which allows multiple antennas to connect one Reader. But there is a trade-off of space consumption when installed for use.

The set up environment mimics a typical intersection and the RFID Readers are mounted to the imaginary traffic lights, which are ‘Traffic light 1’ and ‘Traffic light 2’ in Fig. 7(c). In this setting, one Reader is installed to capture the traffic information of one uni-lane at one intersection. The evaluation has shown that all identified specifications in Section III are implemented successfully. Figures depict the details of the testbed evaluation: Fig. 7(a) is the Reader, Fig. 7(b) is an example of a vehicle with a registered tag, and Fig. 7(c) is an experimental setup.

The experiment, however, serves the purpose of verifying our configuration of the system only. And it needs to be further tested under practical constraints of real-life environments including, but not limited to, weather conditions, interference of physical objects, and spatial constraints. Besides, more experiments should be conducted to find the optimal configuration of the system, for instance, the location of tags for different types of vehicles, the ideal position of RFID readers in a given environment.

## VI. Future Work

The testbed system introduced in this paper opens up a range of new research opportunities for us and will be continuously tweaked and expanded to investigate issues involving decentralized or even centralized traffic control using RFID technologies. Below are an initial set of the research questions that have been formulated, while the list will grow fast as more experimental data and user needs are gathered.

### *A. Technical Perspective*

How capable and reliable is the passive RFID technology in detecting tags on the roads (e.g. detection range and rate and their association with speed of vehicles, number of vehicles, environmental conditions including weather, etc. [13])?

What are the ideal configurations of the system to yield the optimal performance (e.g. location and position of RFID reader installation, location of tags attached to vehicles)?

What factors need to be considered to make the system maintenance easier and more cost-effective (e.g. heterogeneous devices, scalability of the system)?

What other types of embedded and sensory technologies can be developed for similar purpose? How can those technologies be integrated together and contribute to different perspectives of traffic management?

How can the system take full advantage of a distributed system while serving primary functionalities of a centralized system? What information needs to be stored at each intersection and shared among adjacent junctions and what needs to be sent to the central server? What data attributes should be stored locally or at the central server? What are the decision criteria for those attributes?

What is the optimal way of supporting communication between adjacent intersections (e.g. how to determine neighbour junctions dynamically using ad-hoc communication)?

What are the security and privacy issues that need to be addressed in order to make the system deployable (e.g. encryption, less invasive data gathering methods)?

### *B. Usability Perspective*

What are the current information needs and workflow of police officers? What decisions are made in the process of controlling traffic? And what information is used at present and what other information will potentially be useful?

What are the design points that need to be addressed to make the system (especially the IoT-based application) blend well with the current workflow of police officers and help reduce their cognitive load?

What is the ideal design of information architecture and user interface that satisfies police officers’ information needs more efficiently, yet does not pose a steep learning curve?

How can the system support the technicians who maintain the system, both hardware and software?

### *C. Further Explorations*

Can the system make use of other sources of information besides the traffic data collected by RFID readers (e.g. traffic-related information available online [14], video surveillance feed [15])?

Can the data collected by RFID readers be used for other purposes, serving other types of systems or users (e.g. centralized traffic analysis, traffic prediction, road construction or maintenance planning)?

## VII. Conclusion

This paper discusses the ongoing research on the building of a smart traffic management system. The practical problem is defined, the solution is proposed, and the initial test-bed system is prototyped successfully. However, there are a number of issues to be addressed before the solution can be tested and applied to real-life problems such as heterogeneity of devices, concurrency of the services, responding times, data volume, human factors, and intelligence recommendations. Upon the success of solving further issues, the results will be reported in the near future.

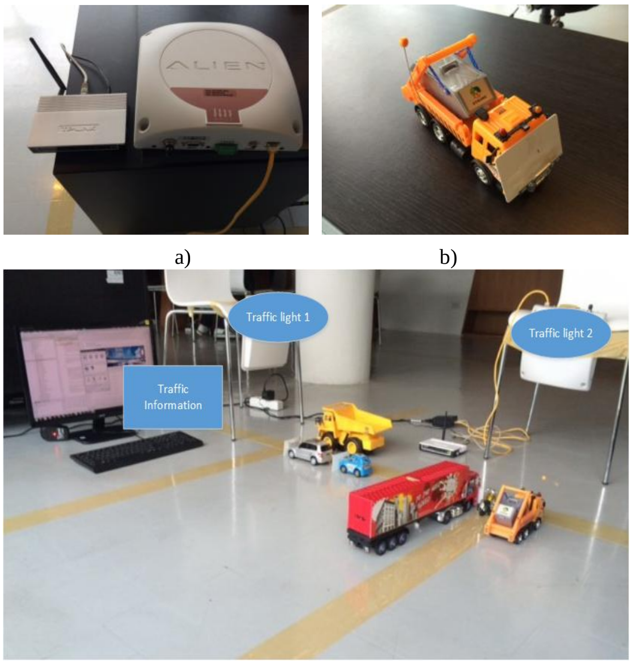


Fig. 7. Demonstration set up: a) RFID Reader connected to a router. b) A miniature vehicle with a RFID tag. c) Testbed environment.

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