Passive RFID for Intelligent Transportation Systems

Kashif Ali and Hossam Hassanein
School of Computing, Queen's University,
Kingston, Ontario, Canada, K7L 3N6
{kashif, hossam}@cs.queensu.ca

I. INTRODUCTION

Technology automates most of our daily activities, from the thermostat to the landing of Boeing aircraft including vehicle transportation. The projected 8.5 million driving related deaths by the year 2020 is the motivating force underlying the numerous academic, commercial and governmental engagements in technology adaptation for vehicles namely, Intelligent Transportation System (ITS), to mitigate the situation. Technology has found its way in ITS as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) paradigms. These paradigms rely on the active communication and sensing, e.g., WiFi, WiMax, radar, active RFID tags and so forth. These active sensing and communication components require consistent battery source, increase the device footage, its cost, and marginalizes its convenience – hindering adaptation by the vehicle owners.

Vehicle driving consists of four basic functions: sensing, perception, judgment and action. ITS main goals are the sensing of the driving environments and assisting drivers in operating vehicles with safety and convenience. ITS operates in two modes namely, stand-alone and co-operative. In the stand-alone system the vehicle, termed as Intelligent Vehicle (IV) [1], is equipped with on-board sensors such as short-range radar, computer vision, active tags and so forth, and are used in applications such as adaptive cruise control, blind spot detection, lane keeping assistant, etc. In the co-operative system, the on-board sensors are augmented with the information flowing into the vehicle from outside source(s). The information from outside source is obtained using two mechanisms such as ad-hoc wireless communication, i.e., the V2V model and the fixed infrastructure based wireless communication, i.e., the V2I model.

In our opinion existing approaches, based on active sensing and communication model have two basic fundamental limitations; high equipment cost and design limitations to utilize non-Intelligent Vehicle (non-IV), i.e., the vehicle without any on-board ITS sensor (over 260 million in US), to assist in sensing and information relaying.

II. PASSIVE ITS ARCHITECTURE

In this paper, we propose a passive solution which is low-cost, facilitates high adaptation rates and utilizes the non-IV vehicles to assist in ITS applications. RFID technology, a prominent identification technology, has the potential to turn everyday objects into a mobile network of nodes, which can then be used to track and trigger events. Our solution makes use of RFID passive tags [2] – a low-cost, paper-thin and battery-less device. The passive RFID tag is augmented with the registration sticker of the vehicle's (IV or non-IV) license plate, as is depicted in the upper-right corner of the Fig. 1. The IV's, equipped with RFID readers and directional antennas, by tag interrogation process can identify vehicles presence within its proximity. The tag memory contains information about the tagged vehicle, e.g., class, physical dimensions, on-board ITS sensors – if any, proprietary data, etc. and the relayed data stored by any IV's readers. The basic philosophy behind such system is to make use of non-IVs for low-cost sensing and data relaying.

The proposed passive ITS architecture has many advantages. Firstly, it is exceptionally low cost, passive tag are under 10cents. Secondly, the non-IVs can now assist, without any on-board ITS sensor or communication modules, in sensing and data relaying for ITS applications. Thirdly, with each vehicle been tagged (both IVs and non-IVs), certain convenience ITS applications, e.g., real-time traffic updates, can be articulated in cost-effective manners. And lastly, it can support broad-range of ITS safety, e.g., forward collision warning, safe gap advisory, etc., convenience, e.g., adaptive cruise control, blind spot monitoring, etc. and management applications, e.g., traffic conditions, congestion avoidance, etc.

We now briefly outline stand-alone and co-operative systems based on the anticipated ITS architecture.

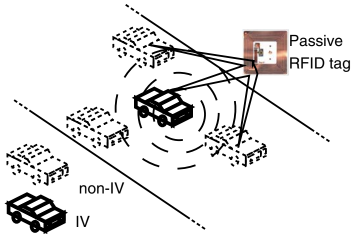

Fig. 1. Stand-alone passive tag based design

A. Stand-alone System

In the stand-alone system, Fig. 1, the IV are equipped with RFID which continuously interrogate its proximity to determine the presence of passive tags, i.e., other vehicles. Four directional antennas, possibly more, mounted at the front and rear corners of the vehicle, assist in determining the presence of other vehicles. By varying the radiated power level for different directional antennas the vehicle can determine the front vehicle position, speed, acceleration and heading, all at low communication latencies. Such information assists in implementation of Adaptive Cruise Control (ACC), Cooperative ACC (C-ACC), headway advisory, forward collision warning, platooning and limited lane change support.

B. Co-operative System

The cooperative system is an extension of the stand-alone system in which, in addition to on-board reader, road-side assistance for tags interrogation is readily available. The road-side equipment collects the data, both the tag data (by readers) and sensed data (by sensors), to relay to base-station (using wired or wireless) and the IVs. Such co-operative system is conceptualized in Fig. 2. The existing Floating Car Data (FCD) schemes [1] relay information about current travel conditions. However, they can only do so using vehicles which are equipped with wireless modules, i.e., the IVs. Our proposed architecture, on the other hand, store information on both IVs and non-IVs passive tags, which can then be interrogated and read by either an IV or road-side reader, facilitating immediate information dissemination.

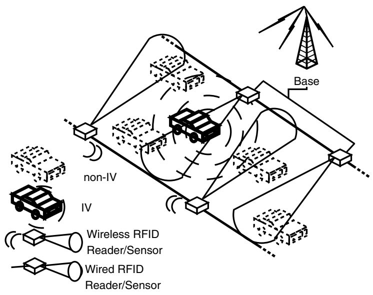

Fig. 2. Co-operative passive tag and active communication based design

III. AN APPLICATION – ADAPTIVE CRUISE CONTROL

The Adaptive Cruise Control (ACC) allows the driver to set a desired speed as in the normal cruise control but with additional functionality, i.e., the vehicle acceleration is adapted in accordance to the vehicle directly ahead, in same lane at "some" fair distance. The vehicle is diverged to the initial desired speed as the forward car either changes its lane or goes out of the range. The RFID reader mounted on the car determines the distance R, hence the speed and acceleration of the forward vehicle by varying its power levels P and based on the backscattered signal strength P_{back} from the passive tag as [2]:

$$R = \frac{\lambda}{4\pi} . \sqrt[4]{\frac{k.P.G_{Reader}^2 . G_{Tag}^2}{P_{back}}} \qquad (1)$$

where G_{Reader} and G_{Tag} are the antenna gain of the reader and the forward vehicle tag, respectively. By adjusting the power level, the reader creates different ranges, each of size 'step', shown in Fig. 3-a. The maximum range are divided into three subsets namely, free range, alert range and danger range. The free and alert range differs in their 'step' (δ) values, which latter having more smaller value. The small value helps to extract fine-grained information about the forward vehicle then would a large value. The cruise control is turned off as the forward vehicle comes within the danger range. The high-level pseudocode for the adaptive cruise control is shown as Algorithm-1. With small Δ, the ACC algorithm can determine the vehicle mobility with fine coarse granularity. The vehicle speed is adjusted based on the threshold Δ_{thresh} of the power change rate ΔP. The threshold Δ_{thresh} determines the vehicle speed smoothness. With tag interrogation duration of few millisecond, based-on the EPC Gen2 class1 RFID tag [3], the scheme can determine vehicle speed in minimal time. We are further analyzing the results and plan to have full scale prototype to determine practical feasibility, in near future.

Algorithm 1 Adaptive cruise control high-level pseudocode

```
wait until car comes within the reader range.
Adjust power-level 'P' to match distance-to-car (1)
while car is within Alert zone or Free zone do
    if CarFound(P - $\delta$) then
        P $\leftarrow$ P - ($\delta$ + $\epsilon$)
    else if CarFound(P) then
        Maintain existing power
    else if CarFound(P + $\delta$) then
        P $\leftarrow$ P + $\delta$
    end if
    if $\Delta$P $\geq$ $\Delta_{thresh}$ then
        Accelerate for $\Delta$P > 0, de-accelerate for $\Delta$P < 0
        Adjust $\delta$ based-on the car zone
    end if
end while
```

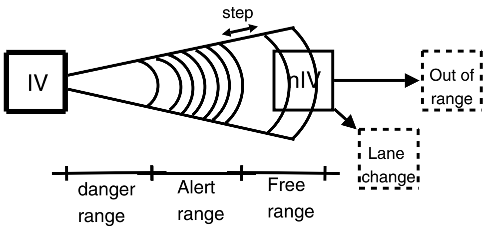

Fig. 3. Adaptive cruise control scheme using passive RFID

IV. CONCLUSION

In this paper, we present an architecture based on low-cost passive tags in ubiquitous manner, a novel concept which utilizes non-IVs, along with IVs for sensing and information dissemination for ITS applications.

REFERENCES

[1] R. Bishop, *Intelligent Vechicle Technology and Trends*. Artech House Publishers, 2005.
[2] K. Finkenzeller, *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification*. New York, NY, USA: John Wiley & Sons, Inc., 2003.
[3] *EPC Radio-Frequency Identity Protocols Class-1 generation-2 UHF RFID Protocol for Communicaitons at 860 MHz – 960 MHz*, Version 1.1.0, 2005.