AHS Road-to-Vehicle Communication System

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1. Introduction

Advanced Cruise-Assist Highway System (AHS) has established itself as the system in the total ITS concept of Japan providing services aimed at improvement of road traffic safety, increase in transport efficiency, and alleviation of environmental problems.

Realization of AHS services requires road-to-vehicle communication (RVC) for sensors installed on the side of roads to communicate road transport data to the vehicle in motion. This type of communication demands that the system has distinctive features not realized by existing dedicated short-range communication (DSRC) and public mobile communication. The report herein defines the requirements for AHS road-to-vehicle communication and for the data communication system involved and presents the concept of the AHS data communication system.

2. AHS User Services and Service Area

AHS research and development in Japan is under way through coordinated efforts between the Ministry of Construction and Advanced Cruise-Assist Highway System Research Association(AHSRA). Under this project, AHS services are classified into AHS-i, AHS-c, and AHS-a. AHS-i is designed to transmit alarm to driver on obstacles and danger detection data gathered by roadside sensors. AHS-c triggers control signals to regulate vehicle speed and steering based on the danger data from roadside sensors. AHS-a realizes automated cruising through unassisted data-gathering and cruising control. [1,2]

Under this project, 19 principal user services have been identified from the standpoint of safe cruising and of transport efficiency and environmental control, corresponding to the types of service delivered. [3] Based on these services, the service areas that are to be provided by RVC are defined according to the range of sensor detection and distance of vehicle control. Based on the size of each service area, the principal user services have classified as shown in Figure 1.

3. Analysis of AHS Services

In the study into implementation of AHS services, system analysis was conducted, and use cases developed. The use cases are shown as system behavior seen as scenario for object behavior from the user perspective. [4] Figure 2 shows the principal user services corresponding to 7 use cases.

Use cases are described in unformalized text. The use case for "collision prevention" is shown here as an example.

Use Case: Collision Prevention

When a vehicle enters the area where the corresponding service is provided and service demand is sent to the AHS Service Center, registered data of the vehicle is returned from repository of moving object behavior forecast, repository of road facilities, weather, and road surface condition data from cruising environment data, and data on surrounding vehicles, pedestrians, and obstacles from road conditions. Based on the said data and data on vehicle surroundings picked up by on-board sensors, as well as vehicle position and direction data, safety of the cruising direction is studied. If danger is projected, deceleration control data is generated to trigger caution and alert and to prevent danger, following by output to user input/output device or automated control with the vehicle controller.

If the driver overrides the alert or automated deceleration, control data generation is adjusted.

At the AHS Service Center, level of collision possibility is calculated for each vehicle, based on moving object behavior projection, cruising environment, and road condition data. The level of danger calculated is provided to vehicles as demanded. At the same time, alarm is displayed on roadside information boards for non-AHS vehicles.

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In developing use cases, visual representation shown in the use case map [5] is employed as tool in aiding communication between the user and the analyst. Figure 1 shows the map for "collision prevention" use case.

4. Quality of AHS Service

The internal factors that affect the quality of AHS services are studied here from the standpoint of efficacy and safety.

4.1 Efficacy

Factors that potentially determine the efficacy of AHS services are the following.

(1) Data efficacy: Whether the information provided is effective. This is determined virtually wholly by service design.

(2) Data error: Information provided may have error, which is caused by sensor detection error and transmission signal error in RVC. Since the error will make accurate data transmission impossible, service efficacy is lost. Transmission signal error can be detected nearly completely through message authentication.

(3) Data transmission time: Time is required for transmission from the information source to the destination, consisting of sensor detection time, RVC transmission lad, and vehicle control processing time. If the total length of the time required exceeds a certain level, most of the efficacy of AHS service is lost. For this reason, retransmission to regulate signal error cannot be used.

(4) Availability: Representing the ratio of delivery of information needed to the destination, this is restricted by device failure, RVC obstruction, and limitations of the service area. In relation to communication obstruction, it is likely to be caused by the following.

* Shadowing caused by obstruction of communication path by large vehicles
* Multipath phasing
* Circuit overflow caused by excess in the number of endusers in the service area over the number of circuits.
* Communication processing lag in handover between base stations

4.2 Safety

The following are internal factors in the system likely to affect road traffic safety seriously. [6]

(1) Data alteration: Information to be provided is altered. If malice is involved in alteration, traffic can be confused, causing accidents.

(2) Bugging: Information on private individual and each vehicle can be bugged. If movement of specific individuals or vehicles can be tracked by bugging, it is equivalent to assistance to murder, kidnapping, burglary, etc.

Since AHS is aimed to provide services that improve safety, decline in safety in the course of service implementation is not permissible. For this reason, full countermeasures must be taken on factors that compromise safety.

In dealing with information alteration, authentication of information source and message is effective. In preventing bugging, login and message encryption that does not reveal user ID and vehicle ID is effective. These measures are possible through application of encryption technology.

It is must be noted that user authentication in conventional information and communication system is hazardous in terms of safety. In ITS, user authentication should be kept at a minimum. For this reason, prepaid system that does not require user authentication is preferable for on-line tolling.

Table 3 shows the quality grade required for the major factors that affect the quality of service for each level of cruising support service. AHS-c and AHS-a require higher quality in information and communication system compared to AHS-i.

5. The Concept of the AHS Information and Communication System

At AHSRA, the AHS information and communication system that meet the aforementioned requirements and road-to-vehicle communication system (new DSRC) that is the main component of the system are being developed. Figure 2 shows the configuration of the AHS information and communication system.

This system consists of vehicle subsystem, roadside subsystem, and center and backbone subsystem. Traffic information generated by the roadside subsystem is transmitted to the vehicle subsystem via RVC. Types of vehicle subsystems are AHS-i model vehicle, AHS-c model vehicle, and AHS-a model vehicle. AHS-i services is provided to AHS-i model vehicle; AHS-i and AHS-c services to AHS-c vehicle; and AHS-i, AHS-c, and AHS-a services to AHS-a vehicle. Roadside information boards provide AHS-i service to drivers of non-AHS vehicles.

The new DSRC system creates a medium-range (approx. 100-m) service area from each wireless base station. By installing multiple number of base stations adjoining each other, the size of service area can be controlled at will. Moreover, circuit allocation can be adjusted dynamically, reducing the number of communication circuit depending on concentration of cruising vehicles.

To realize the required safety level, facility authentication employing public key and message authentication employing hush coefficient are to be adopted.

Figure 3 shows the procedure for service connection under the system. When a mobile station receives pilot and announcement received from the control station, it transmits channel demand and received circuit allocation. Clock is synchronized by employing time service, and network address is obtained upon demand to the network. Next, after KDC authentication by connecting to the key distribution center (KDC), service ticket is demanded and received. When service is demanded by presenting the service ticket to the service server, validity of the service ticket is studied, and service is provided when ticket is validated.

6. Conclusion

The items required for road-to-vehicle communication in providing AHS services have been defined, and configurations of the new DSRC and AHS information and communication system that meets the demands have been shown.

RVC needs to boost availability of wireless circuits through creation of small wireless zones in range of roughly 100 meters, dynamic circuit allocation, and high-speed handover. In addition, the RVC device preferably should have positioning feature along with communication because of the need to assess positions of cruising vehicles in many ITS services.

Moreover, data security must be increased to assure safety of services provided. To achieve this, protection of user information is necessary along with application of encryption technology in message authentication and information source authentication. However, trade-off between safety and convenience is necessary for those among ITS services that require user authentication, such as reservations and fee payment.

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Reference

[1]"Comprehensive Plan for Intelligent Transport System (ITS) in japan"
http://www.moc.go.jp/road/ITS/index.html

[2]"ITS HAND BOOK"
http://www.nihon.net/ITS/index/indexHBook.html

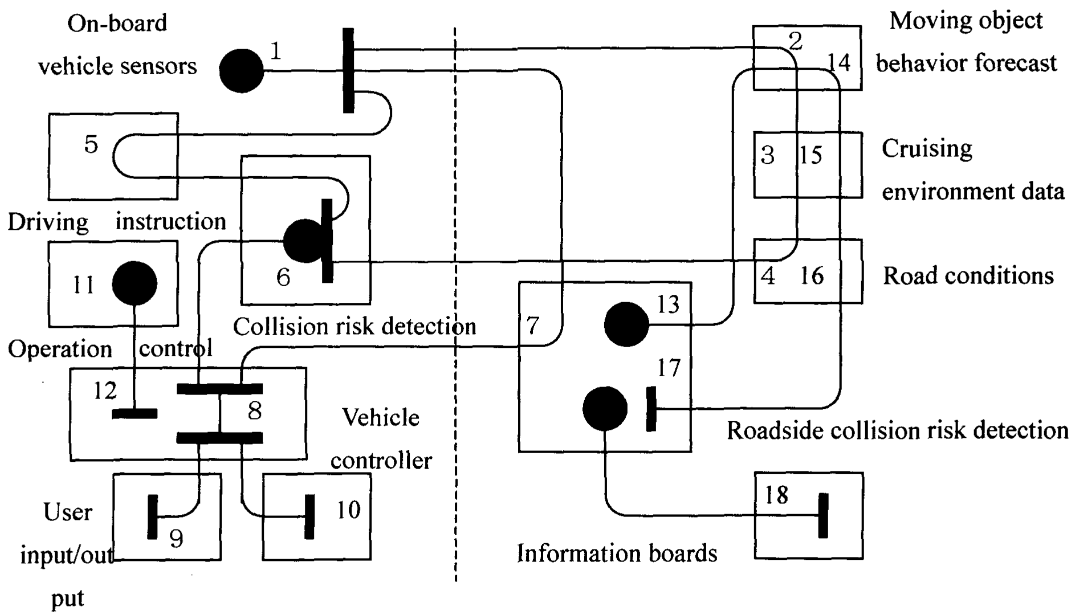
[3]"AHSRA REPORT vol.2" Sep.1998

[4]I.jacobson, M. Christeron, and G. Overgaard,Driven Approach,"Addison-Wesley,1992

[5]R.J.A.buhr and R.S.Casselman,"Use Case Maps for Object-Oriented Systems," Prentice-Hall,1996

[6]P.A.Karger and Y.Frankel, "Security and Privacy Threats to ITS," 2nd World Congress on ITS,1995

Figure 1: User Case Map: Collision Prevention



Functions

1: Demand collision prevention service

2: Return of position data of registered data

3: Return of road structures, weather, and road surface condition data

4: Return of surrounding vehicle, pedestrian, and obstacle data

5: Return of vehicle surroundings data and own-vehicle position & direction data

6: Calculation of collision risk level

7: Collision risk level read from roadside

8: Alignment with control instructions from other services and generation of control signals

9: Display or sound output of cautions and alarms

10: Vehicle navigation & deceleration control

11: Override signal produced

12: Alignment of control signal generation

13: Data demand

14: Return of registered vehicle position data

15: Return of data on surrounding vehicles, pedestrians, and obstacles

16: Calculation of collision risk level

17: Display of caution or alarm

Figure 2: Configuration of the AHS Information and Communication System

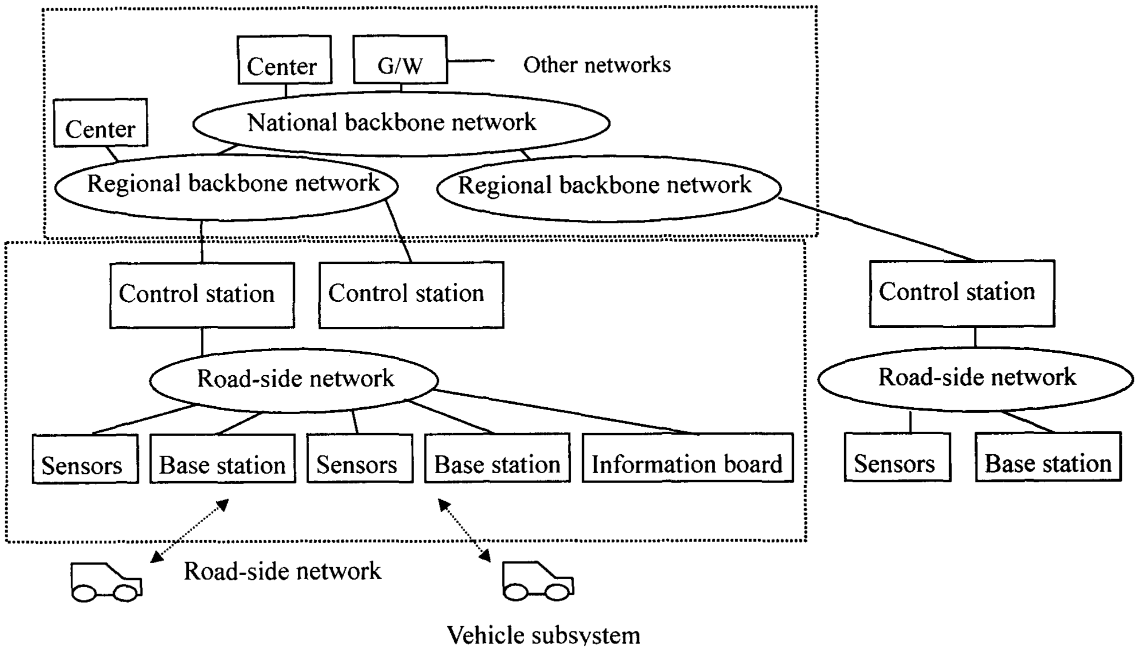


Figure3: Service Connection Procedure

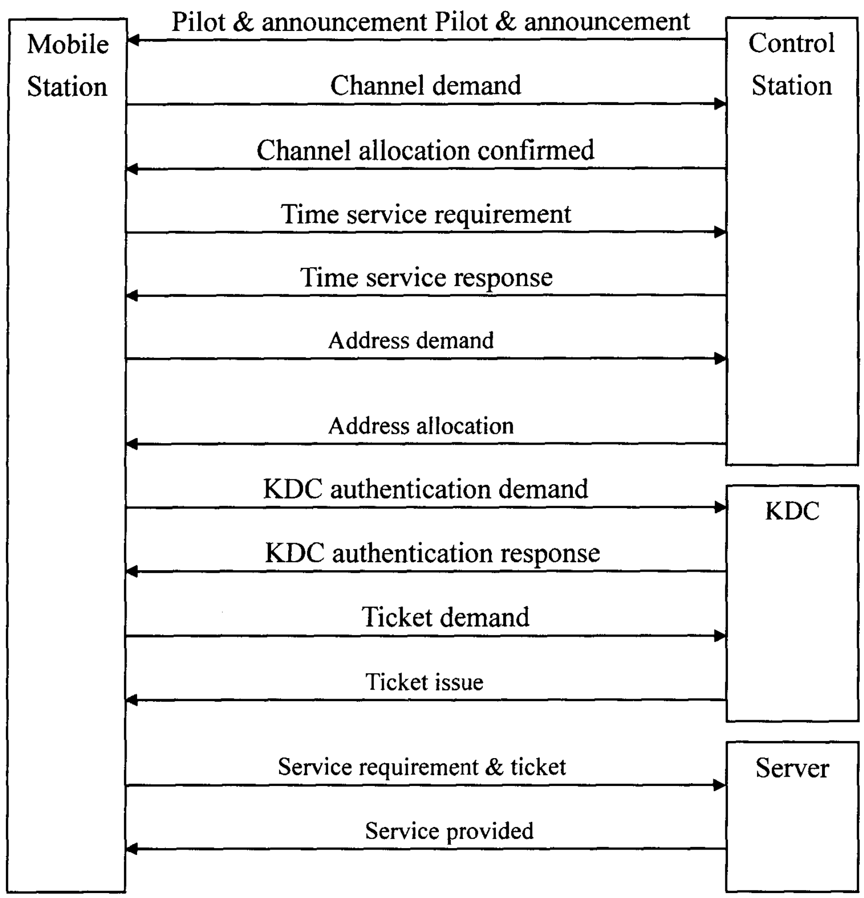


Table 1: Types of Principal User Services by Size of Service Area

Service area	Safety User Service	Efficiency User Services
Small-range (several tens of meters)	• Prevention of crossing collisions • Prevention of collisions with Predestrians crossing streets • Prevention of right turn collisions • lake keeping(straight lane)	• optimum starting behavior(crossroad)
Medium-range (several hundred)	• Prevention of collisions with Obstacles • Lane keeping(curves) • Safe lane changing	• Maintaining suitable headway • Optimum speed • Optimum lane utilization rates • Optimum merging/diverging • Optimum lane changing • Reduction of stop and go
Continuous (several kilometers)		• Reduction of headway(platooning)

Table 2: AHS Service User Cases

User Cases	Principal User Services
Headway keeping	Maintenance of safe headway / Maintaining optimal headway / Reduction of headway / Optimum starting behavior (intersection) / Keeping roads open
Platooning	Reduction of headway (platooning)
Lane keeping	Lane keeping(straight lane)/Lake keeping(curves)
Collision prevention	Prevention of collisions with obstacles/ Prevention of right-turn collisions / Prevention of left-turn collisions / Prevention of collisions with pedestrians crossing street / Prevention of head-on collisions (collision aversion) / Safe lane changing
Traffic flow optimization	Optimal speed / Optimum land utilization rate / Reduction of stop and go
Stopping at stop points	Prevention of head-on collisions (at stop points) / Prevention of accidents at railroad crossing
Traffic flow stabilization	Optimum lane changing / Optimum merging/diverging

Table 3 Grade of Service Quality Required in Information and Communication System

Service Level	AHS-i	AHS-c	AHS-a
	Information supply& alarm	Control	Automated cruising
Information error	Medium	Small	Small
Information transmission time	Medium	Small	Small
Availability	Medium	High	High
Safety	Medium	High	High