SIMULATION IN AUTOMOBILE INFORMATION AND COMMUNICATION SYSTEMS

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ABSTRACT

A large number of R & D projects in automobile information and communication systems have been achieved in these twenty years to improve various aspects on automobile usage. Examples on simulation for evaluation of these systems such as these on road to vehicle communication, inter-vehicle communication, and vehicle guidance are shown.

AUTOMOBILE INFORMATION AND COMMUNICATION SYSTEMS [1]

Historical review

In the middle of 1960's, new information and communication systems for automobile traffic in highway were being developed chiefly in U.S. Their purposes were offering of traffic information, route guidance, emergency communication, aid for accident suffered or disabled vehicles, monitoring of road and traffic situation, automatic debiting, management of commercial vehicles and automatic driving and others.

Basic concept of automobile information and communication systems is to realize the better co-ordination in automobile traffic by forming communication links among automobiles and ground infrastructure. Reducing traffic congestion, pollution and noise, increasing traffic safety, comfort and amenity in travel, saving travel time, increasing efficiency and economy are the measures of the systems.

ERGS (Experimental or Electronic Route Guidance System) reported in 1970 in U.S. adopted two-way spot communication of 41bits data between vehicles and ground for route guidance. Reading guide table stored at a roadside unit by addressing the destination data from each vehicle gave the turning direction of the vehicle at the downstream intersection with the indication of arrow at its on-board display.

The CACS (Comprehensive Automobile Control System) project in Japan was executed from 1973 to 1979 supported by MITI (the Ministry of International Trade and Industries) with the budget of 7.3 billion Japanese Yen. Dynamic route guidance with vehicle/ground spot data communication similar to the ERGS, except that its improved performances by using 144bits, was to be an essential subsystem. Other subsystems such as on-board displays for drive information and in-car radios for traffic incident information were added to make the system a comprehensive one. Field experiments were carried in 30 km^2 pilot area in Tokyo over six months from 1978 to 1979. [2]

The ALI project in West Germany was almost the same as the ERGS and the CACS projects. It executed field experiments in freeways connecting 8 cities in 1979, and its follow up resulted the recent development of ALI-SCOUT system demonstrated in Berlin in 1990.

Table 1 shows the projects developing automobile information and communication systems in Japan, which were continuously and competitively promoted from the 1970's to the present by the different governmental organizations.

In the early 1980's, several small scale, follow-up projects or practical use such as bus information systems in street, travel-time monitoring systems in freeway, standardization and technological improving in road/vehicle communication were carried out. Newly available micro-electronic devices were used in these systems. Developing autonomous navigation systems using a CD-ROM and a CRT display for on-board audio/visual equipment was challenged by car manufacturers in these years. Among them, the basic concept and applications of inter-vehicle communication were investigated by the authors.

Recent trend

The overall regal deregulation of communication in Japan in 1985 stimulated the companies with the expectation on enlarged business opportunities in information services along highway. After two years of preliminary study chaired by the author, the RACS (Road/ Automobile Communication System) project was executed by the Ministry of Construction (MC) and 25 private companies from 1986 to 1990 to develop vehicle/ground digital communication network using "beacons" for spot communication. The feature of RACS system is the add-on configuration of three types of beacons; Location beacon (one-way/static information), Information beacon (one-way/dynamic information) and Communication beacon(two-way/messages). [3]

In the term of the RACS project all types of beacons were successfully examined. A new type of beacons using sub-microwave frequencies in the 2.5 GHz region was developed with transmission speed of 512 Kbps at a vehicle speed of 120 km/h.

The AMTICS (Advanced Mobile Traffic Information and Communication System) project was initiated in 1987 by the National Police Agency (NPA). An association under the NPA executed the project with 59 private companies participated. [3]

AMTICS aimed at direct presentation of traffic information from control centers to drivers having on-board audio-visual equipment. It was featured the use of commercially available mobile data communication systems called tele-terminals. However, multiplexed data channels in FM radio are now assumed for practical use because increase of tele-terminal units are rather slow and the areas covered are limited.

The project was successfully demonstrated in pilot experiments, first in 1988 in metropolitan Tokyo and second in 1990 in Osaka where the Flower and Green Exposition was held.

For realizing automobile information and navigation systems in the near future, the Ministry of Post and Telecommunication (MPT) which is responsible for administration on radio communication and broadcast joined with MC and NPA, and they are now starting to promote a new system called VICS (Vehicle Information and Communication System). Principal task of them is to co-ordinate in exchange of traffic information and in appropriate use of radio media.

A large scale of programs named PROMETHEUS and DRIVE which include a wide range of R & D projects are now undergoing with close co-operation among people in Europian countries. The huge program named IVHS (Intelligent Vehicle/Highway Systems) was rapidly initiated in U.S. under the leadership of DOT (Department of Transpoprtation), and many people from federal/local government, from universities and industries joined the program. With these activities including those in Asian region, further progress in "Info-mobility" is expected in the present decade and in the new decade in the 21st century. [4]

EXAMPLES OF SIMULATION

It is needless to say how important is the simulation technology for development of these vehicle information and communication systems. They are complex systems in which experimental verification in the field is difficult from both aspects of automobile traffic and of radio propagation. Legal regulation in usage of road and radio wave also gives the limit for it. Moreover, efforts to make understanding and to form consensus of the public for justification of large investment are required. Simulation is the strong tool for them. Among the vast examples done, some of them to which the author was involved are shown. [5], [6]

Evaluation of route guidance effect [2]

In the CACS project in 1970's, a simulation program named "ATRAS" was developed by Toyota Corporation for evaluation of route guidance effect of the system. It was attempted to handle each individual vehicle with its destination in the large scale of road network. The program was very huge, and it cost and took time for run at that age.

A simulation was done by the program where dynamic route guidance for the shortest path was assumed at 1,500 key intersections in metropolitan Tokyo. Significant effect was achieved when only 20% of vehicles are equipped with in-vehicle units for route guidance. On the contrary, the system is suffered with instability when more than 50% of vehicles were guided for the shortest path. It was solved when traffic is diverted to plural routes for approximately balanced state of equal travel time. The result of simulation showed that the gross travel time is reduced by approximately 6%. It corresponds a saving of 80 billion Japanese Yen at that time.

Evaluation with hardware traffic simulators [7]

In the early 1970's, the author developed two hardware simulators named TRN*SIM I and TRN*SIM II for evaluation of traffic control strategies including dynamic route guidance. These simulators adopted special architecture for highly parallel processing to realize high speed simulation with microscopic models. An extremely simple model was used in the former, where only a single bit in a memory indicates presence of a vehicle in some road section. The model was revised in the latter, where a byte in a memory indicates type, speed or destination of a vehicle. Vehicle's drive is calculated with a simplified model of car-following.

The hardware simulator TRN*SIM I was extensively used for evaluation of signal control strategies in many cases. TRN*SIM II was a rather complex system and it was used for simulation of traffic phenomena such as dynamic variation of traffic jam and occurrence of shock waves in congested flow. However, its model validated with observed data was used later in evaluation studies of control strategies by the authors.

Performance evaluation of mobile packet communication with small zones [8], [9]

As the advanced stage of vehicle information and communication systems such as ERGS, CACS and RACS in future, the author proposed a system with the more extensive use of spot communication (Fig. 1) in 1986. In the system, small communication zones of about 10 meters long are continuously allocated along the road. Singular digital communication channel is used commonly for every vehicle with time sharing basis.

Two kinds of data, one for drive control of vehicles and the other for data communication is assumed. To achieve reliable and efficient communication during the limited access time of vehicles in a small communication zone is essential in the system. Simplified procedure for communication, switching and transmission control with prediction of vehicles' movement were proposed and examined.

Simulation was done for evaluating this procedure. Wider allowance in response time for transmitting drive data without failure and general data with shorter delay was achieved. To examine a more detailed performance of communication protocol and to verify hardware/software design of in-vehicle/roadside units, a small scale simulated experiment was done by using a hybrid simulation technique.

The system was organized with a scale model of antennas, actual transceivers, simulated controllers using actual software implemented in microcomputers and a minicomputer simulating traffic environment as shown in Fig. 2. Accurate performance of the protocol was verified. Efficiency of about 30% for drive data and more than 70% for general data was achieved.

Performance evaluation of inter-vehicle communication [10]

In 1981, a research group headed by the author was organized to study a novel type of inter-vehicle data communication system which includes radio relay through a chain of vehicles. Purpose of this system is to improve driving safety with enhanced "conversation" between neighboring vehicles and also to enlarge information collection/offering functions of traffic management systems with co-operation of vehicles.

Problems to solve in radio relay in the system are failure for linkage when a radio wave doesn't reach in sparse vehicle traffic and, on the other hand, failure due to collision of signals in dense traffic. Computer simulation by Dr. Aoki showed as in Fig.3 that appropriate transmission control enables to maintain the system in proper state.

Two types of the system were demonstrated in experiment. The one is to use spot communication between neighboring vehicles. The other is to use conventional radio link of VHF band with short reach. Both systems are proved feasible and are finding appropriate applications.

Performance evaluation of vehicle guidance and its future plan [9]

The author imagines to realize guidance of individual vehicles in traffic flow by using the packet communication system with small zones described above. The more sophisticated control to achieve high level of safe and efficient traffic is aimed at with lane and speed control of vehicles.

A branching control-in a freeway junction and a turning control at an signalized intersection were considered as examples. Effectiveness of control strategies was examined by simulation.

For the more extensive studies on various systems in which drive of each vehicle is controlled with information given by the system, an effective tool for simulation is being developed by the authors.

In the tool, object oriented method is taken in. Any "object", such as vehicles, signals, signs etc., can change not only its information but also its activities. For example, drivers can change thier route or their behavior with information from the control center. Cycle or split of signals can be changed according to dynamic information from vehcles. Simulation of vehicle information and communication systems is expected to be more fast and convenient.

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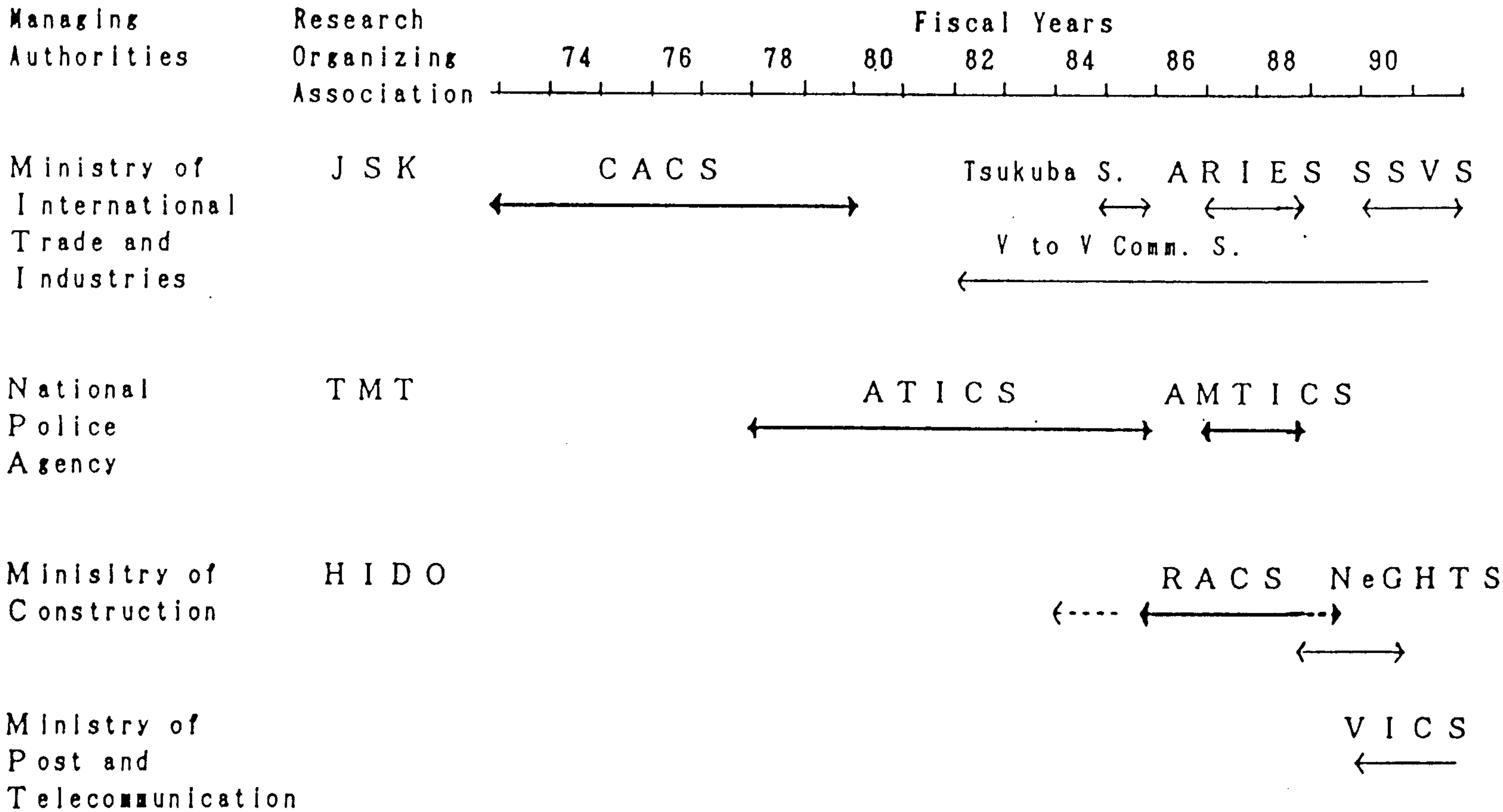
Table 1 PROJECTS FOR DEVELOPMENT OF VEHICLE INFORMATION AND COMMUNICATION SYSTEMS IN JAPAN



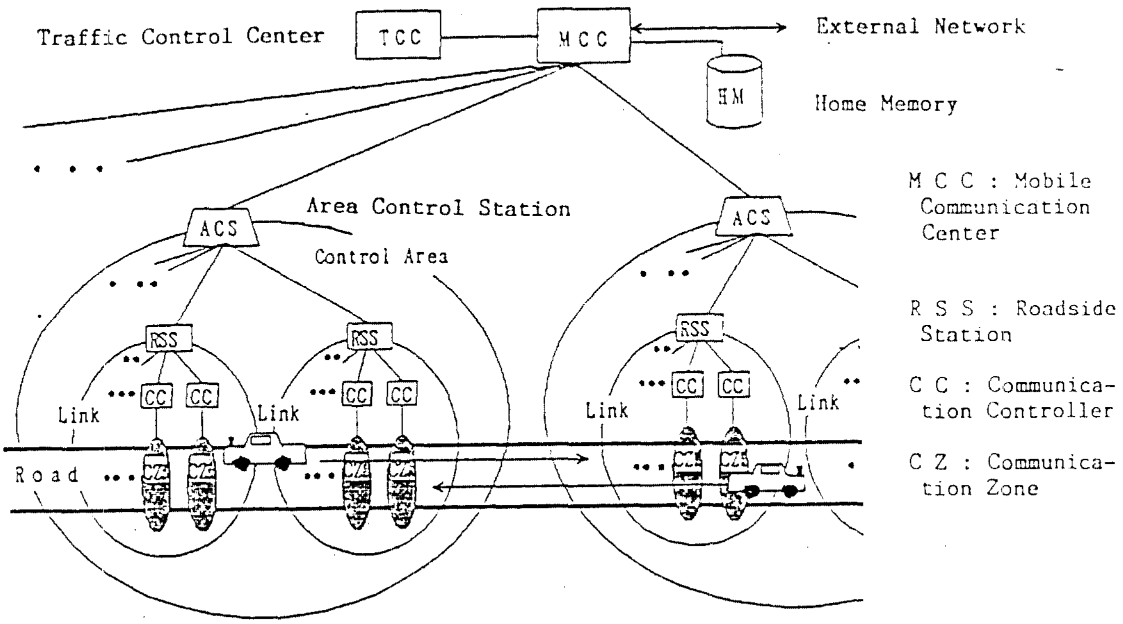


Fig. 1 Configuration of a mobile packet communication system using continuously allocated small zones

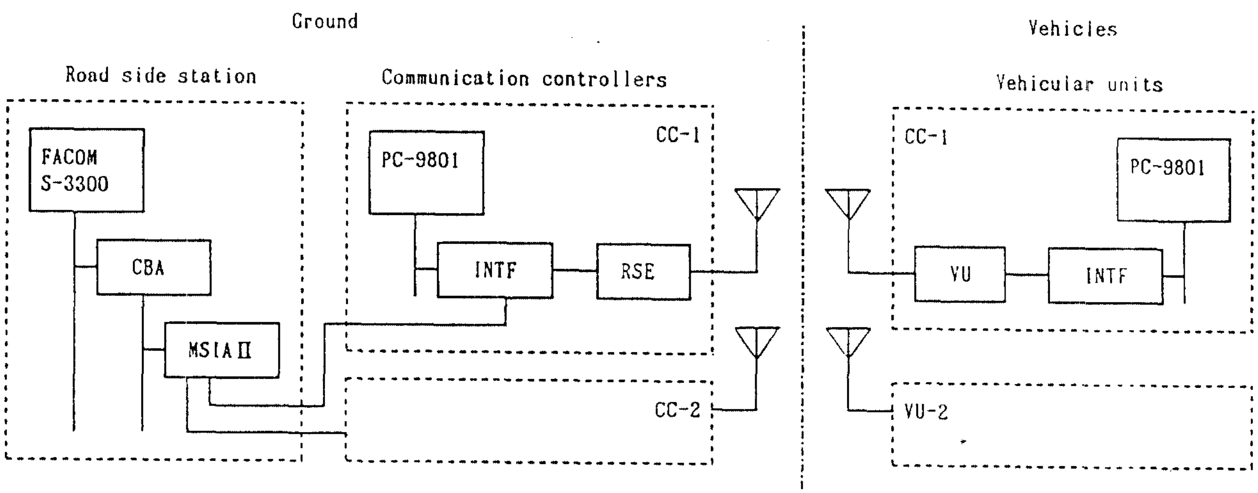


Fig. 2 System cofiguration for simulated experiment

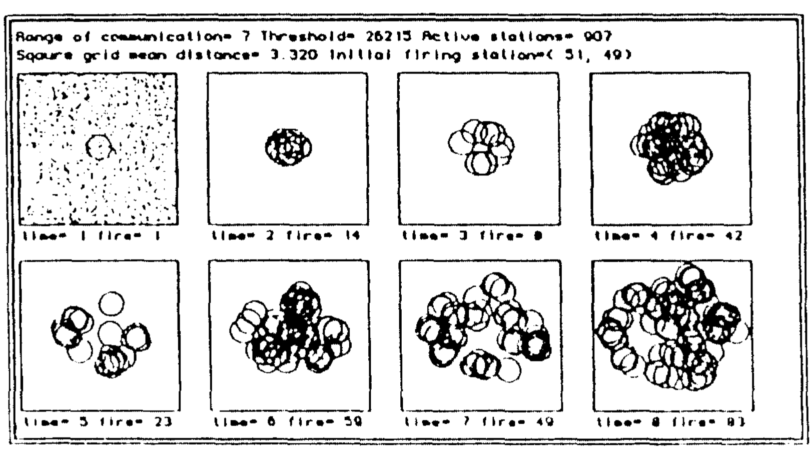


Fig. 3 Packets propagation in inter-vehicle communication (Aoki [10])