An IVHS System Architecture Workshop

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Introduction

The IVHS System Architecture Workshop was supported by a grant from the University of Michigan College of Engineering, and co-sponsored by the IVHS AMERICA System Architecture Committee. It was held on the campus of the University of Michigan on October 24-25, 1991, and included 54 participants from 8 countries (Belgium, Canada, Germany, Japan, Singapore, Sweden, United Kingdom, and the United States).

The general purpose of the workshop was to promote international harmony through science and technology, and the specific mechanism employed was to organize the meeting around five topics arising from current system architecture discussions. These topics might be regarded as meta-questions about the nature of system architectures to be developed over the coming years.

The specific questions posed to the participants are spelled out in the Appendix, which is the original proposal for the workshop, and are reproduced below with the substantive discussion generated by each of them. Position papers were solicited in each of the five areas, and one afternoon of the workshop was devoted to breakout sessions where the authors of the papers (with one replacement) were available as resource people. Questions were posed to each of the breakout sessions to help them focus in more detail on the topics they were considering. Then the entire group reconvened in a plenary session to see what consensus could be achieved on recommendations to IVHS AMERICA and the rest of the IVHS community. While the emphasis was on Advanced Traveler

Information Systems (ATIS), there was recognition and discussion regarding other areas of IVHS activity, such as ATMS, AVCS, APTS, and CVO.

The participants were invited according to a deliberate plan to include representatives of thirteen constituencies. These constituencies were spelled out in the proposal (see the Appendix below). Included were such groups as European, Asia-Pacific, and North American IVHS experts, state and federal government representatives, vehicle and equipment vendors, legal and political experts, members of the IVHS America System Architecture Committee, and consultants in the IVHS community.

Each breakout session had a facilitator and a recorder. The facilitator then prepared a summary of the session discussion for presentation to the following day's plenary session. These summaries were subsequently expanded for inclusion in the final report.

Substantive Inputs and Discussions

Substantive inputs and discussions were organized around the five meta-questions. The inputs from the five commissioned papers and the discussions at the five breakout sessions are thus summarized below in accordance to the five questions.

(1) Is it desirable, or even possible, to aim for common functional requirements for an ATIS system for the entire world? For Europe, Japan, and North America, where do most of the current actions occur? Given the different cultures, geography, demography, perceived user requirements, and so on, in these diverse areas, is it realistic to aim at common interfaces?

In his commissioned paper, Chadwick[1] responded by stating that "the decision on the feasibility and/or desirability of international commonality for IVHS functional requirements is a multi-dimensional one. The factors involved are not technical, for the most part, and are thus not likely to be well understood or accommodated by engineers alone. The factors fundamentally represent a broadened definition of the term "Human Factors". Many of the concerns that drive a decision on internationalization of functional requirements for IVHS have their direct analog in decisions about national functional requirements standardization in the United States."

In the small group discussion, it was suggested that functional requirements should be distinguished from goals/objectives and strategies, as different countries and regions may share the same IVHS functional requirements but may pursue different goals/objectives with different strategies at different stages of national development. This turned out to be the group consensus after a great deal of exploratory discussion.

A number of examples were examined to show that while all IVHS functions, ranging from radio data systems (RDS) to navigation and route guidance, are of interest to the industrialized countries around the world, they have been pursued with different degrees of emphases. Thus, there is already a recognizable consensus in Europe on the RDS standard and the Traffic Message Channel (TMC) pre-standard (which has been agreed to by Great Britain, France, Germany and Sweden), these standards have not been set in Japan or the U.S. In Europe, it is widely agreed that stressing "park and ride" is the right approach to congestion; providing mobility is not an overriding goal (in contrast with the U.S.). Japan and Europe place societal goals higher than user's (driver's) goals, compared to the U.S. Thus, rapid transit is used much more by commuters there than in the U.S. Many European and Japanese drivers use their cars only on holidays or weekends.

Historical and cultural differences have also affected IVHS staging strategies. In Japan and Europe, cities had existed a long time before the automobile arrived; whereas many American cities were planned on the presumption of almost universal availability of the automobile. There are no street names and house numbers in many Japanese cities; thus any route guidance system there will have to differ from that in the U.S. and Europe. With the extremely high land cost in Japan, a single young man may have substantial discretionary spending capabilities yet still not be able to afford to purchase a house. Coupling this with the unusual appeal of "gadget/toy" in that society, the Japanese man spends heavily on a car and TV. This is one contributor to the large and rapidly growing market of navigation systems in the car, which, while currently not very useful, are perceived to be "useful someday".

In the U.S., it was contended that the IVHS architecture will involve a set of "core functions" that are independent of geography and cultural boundaries. With mobility apparently "written into the Constitution", as well as personal freedom, the core functions will emphasize providing the drivers with all sorts of information and letting them make routing and other (yellow pages) choices.

(2) Is it feasible to take a normative forecasting approach to aim for common functional requirements for an ATIS system on the basis of alternative future IVHS scenarios? Given the comprehensive and uncertain IVHS of the future, of which ATIS is a part, is it practical to design system architectures now that can accommodate most if not all of the future functions?

In his commissioned paper, Varaiya[2] argued that "IVHS systems influence four kinds of decisions that drivers make during their trip. The corresponding tasks that IVHS systems carry out are route and flow control, congestion control, vehicle coordination, and spacing. A comparison of two scenarios shows how IVHS influence over vehicle behavior can range from minor (under a strategy limited to providing information and advice) to major (under full automation which preempts driver control). The four IVHS tasks have three differentiating features: time scale or the time available to carry out the task; spatial scope of the impact of executing the task on the traffic system; and information span or the extent of information needed to carry out the task.

An IVHS architecture organized in a hierarchy of four layers — network, link, coordination, and regulation — was proposed by Varaiya. "This hierarchy resolves in a natural way the three differentiating features. The architecture can accommodate a wide range of automation strategies from the simplest, which limits itself to providing driver information, to the most complex, which achieves total control of the vehicle. The architecture permits the incorporation of new functional capabilities over time, and encourages a decentralized implementation of IVHS tasks. An open architecture specification is urged as a means to promote rapid development of IVHS and to ensure the interworking of independent subsystem implementations. It is also suggested that IVHS standards should be specified in a formal-mathematical language to simplify later problems of design validation and conformance testing of products."

The small group that was going to discuss this second meta-question found that a number of the basic issues relate to architecture compatibility over time, the central issue surrounding the third meta-question. Therefore this second small group decided to join the discussion of the small group that was devoted to the third meta-question. Their joint conclusions will be summarized in the following subsection.

(3) How necessary is it to achieve compatibility over time? That is, if expanding subsets of ATIS features are introduced which expand IVHS capabilities, how necessary is it that earlier versions continue to function as they did, under new, presumably more capable regimes?

After considering alternative early scenarios, Wall concluded in his commissioned paper[3] that "early implementations of ATIS systems are unlikely to have future-proof architectures. The second-generation implementations will need to consider the wide range of interfaces that need to be made open, if they are not to be made obsolete at an early stage. Future-proof systems will certainly be much more attractive to the customer than single-application systems." What are needed include a new, minimal overhead, OSI Transport protocol and high-efficiency OSI (open system interconnection) conforming upper-layer protocols. "Even if systems are built using open interfaces (once these have been specified) it will be necessary to manage the interconnections and migration route so as to achieve the future-proof objective of offering the end user a system that can migrate to meet the corporate or individual's needs without undue churn of equipment and software investment."

In the small group discussion, there was a consensus that temporal compatibility of IVHS system architecture, especially on the side of the highway infrastructure, should be achieved, even at some cost. Both forward compatibility (to accommodate future needs) and backward compatibility (to accommodate older systems) should be achieved. Backward compatibility is exemplified by U.S. color television standards which were set such that color TV program contents could be received by all the black-and-white TV sets in existence even though the color feature could not be captured by those sets. However, some sacrifice of backward compatibility could be acceptable if the switching cost from old to new standards is relatively low so that the manufacturers of the new system can provide low-cost adapters or simply buy out all the old equipment that is no longer compatible. By contrast, temporal compatibility on the vehicle side is less important as the in-vehicle units are usually junked with the vehicles which have limited life as compared to the highway infrastructure.

There was also a general consensus that a high-level architecture model should be sought, spanning the maximum range of IVHS functionality; that is, across ATMS, ATIS, and AVCS (this last category having been discussed specifically in Varaiya's paper[2]). However, at a more specific level, an important issue has remained unresolved; namely, should we allow (and even encourage) separate parallel development of system architectures for ATMS/ATIS and for AVCS in the immediate future, or should we insist that comprehensive system architectures be developed to span all three categories of IVHS technologies? The current trend seems to be toward separate and parallel development, as system architectures for ATMS/ATIS field tests have in fact been designed without much serious effort to assure their forward compatibility with AVCS requirements. The kind of large competing system architecture projects being recommended by the IVHS AMERICA System Architecture Committee[6] has also excluded the consideration of AVCS. It appears that this trend will continue unless researchers working on AVCS can demonstrate in the near future how different system architectures for ATMS/ATIS may have different capacities to accommodate AVCS functional requirements.

(4) Is it possible to agree on a process which would lead to an accepted set of functional requirements for a geographic region to be determined under (1) above? How should this process avoid the obvious conflicts of interest that come from existing products already in the field?

In her paper, Rantowich[4] has demonstrated that an IVHS system architecture process can be developed using the classical methodology for synthesizing architectures with the following steps: (i) defining the goals, (ii) assessing the largest problems in reaching those goals, (iii) identifying and assessing the entire range of solutions, and (iv) synthesizing, assessing, and refining architectures encompassing these solutions. This entire process can be repeated a number of times, including periodic reviews by representative members from public and private sectors and the academia.

The small group discussion revealed that a very generalized level of systems architecture is needed to assure rapid, extensive, and secure deployment of IVHS. Such an architecture will establish a set of conventions under which many different types of IVHS systems can be deployed in the future, supporting alternative system designs which may or may not be interoperable with one another. Wide applicability of the system architecture is needed to enable broadly functional IVHS that can be tailored to applications and markets as needed, while still achieving an internal orderliness in the design for communication, networking, distribution of processing, data structures, and so on. True interoperability (*i.e.*, where any equipped car can function on any road) must be attained by means of policies and presumably standards that serve to target specific system configurations for adoption. The Federal Highway Administration, for example, could promote such an adoption policy and enforce it to a certain degree by making the provision of federal funds contingent upon adoption of the standard system configuration.

Before creating a system architecture, it would be desirable to conduct a variety of focused studies on plausible IVHS system concepts and to carefully examine existing constructs that have already been created for steering open-system design. For example, the focused study by MITRE has fleshed out specific IVHS architecture concepts[6]. Existing constructs relative to communications functions include the OSI conventions and the governmental specification called GOSIP (Government Open Systems Interconnection Profile)[7].

To foster a transition from "no IVHS" to "lots of IVHS" in North America, the process of system architecture cannot proceed in a vacuum but must involve coalition-building, demonstration of system concepts, coordination of the multi-source industry, development of standards and conformance tests, *etc.* and most important, the identification of user needs as the fundamental basis for setting goals. In this regard, the DRIVE/SEFCO document, "Functional Requirements" for European IVHS, could be used to guide a corresponding effort in North America. Finally, given its user orientation and the comprehensive scope, system architecture should be used as a coordination point for IVHS AMERICA.

(5) What is the appropriate level of compatibility; i.e., can interfaces be specified at some level of abstraction among components of an ATIS system so that any concrete implementation which is consistent with the prescribed interfaces, but which may differ radically within each component from any other system, is acceptable as satisfying the agreed upon "standards"? How can the "hooks" be provided for other subareas of IVHS?

In their commissioned paper, Huber and Komanecky[5] suggested that the following key activities need to be addressed "in order to achieve the desired compatibility between IVHS systems. (i) All user needs must be identified. Users might or might not know what they need. Determining the actual needs is a difficult and necessary task. (ii) Achieving network and application independence will require the adoption of a suite of IVHS standards. The current GOSIP[7] specifications provide an attractive starting point. If agreement can be reached to begin with GOSIP and make modifications from that core decision, much time and frustration will be saved. (iii) Creation of an IVHS Service Definition and Protocol Specification is needed and Z39.50 for Library Application may provide a beginning structure. (iv) The specification of a common application programming interface and the creation of an IVHS object library will speed the deployment of compatible applications. (v) Consistent user interface elements will speed IVHS acceptance but will likely be difficult to achieve for several years. All the above are difficult tasks that will require demanding customers and motivated participants to achieve success."

In the small group discussion, it was generally agreed that while compatibility with products already in the field must be taken into consideration when deciding on interfaces, if the benefits warrant it, changes could be made. On the other hand, the ease with which bridges can be created to minimize the effects of such changes should also be taken into account. As an attempt to identify the interfaces in an IVHS architecture, one could consider the infrastructure to be everything external to the vehicle. Immediately one imagines a central Traffic Advisory Center (TAC). What about the roadside component? What about users at home communicating with both vehicles and the infrastructure? A person might want to provide advice to a driver about a congestion report, or ask a question about congestion in a communication to the TAC. What about the operator of a fleet of vehicles? Do we provide explicitly for the interface between that operator and other components?

Given the many interfaces in the overall system, the general principles agreed by the group were that (1) one should be concerned primarily with the driver/vehicle/infrastructure system, and not sources of input (helicopters, police radios, *etc.*) or consumers of output (radio stations, *etc.*) and (2) it was better to identify at least one or two levels of interfaces below the obvious first level, such as driver-infrastructure, since identical or vacuous interfaces and components could be collapsed later, but it would be harder to break them out at a later time. Thus, the interface between a roadside component and the TAC should be explicitly included. In fact, the group ended up including local, regional, and central components of the infrastructure. Finally, there was an interface identified for a user, possibly at home, communicating with the infrastructure, presumably the central TAC, but not necessarily.

Moving to the level of abstraction for such interfaces, it was agreed that the appropriate level of abstraction would allow the substitution of a new system component (with or without new technology) for an existing component of a system as long as the new component satisfied the interface description and protocols. In this sense, it had to be "plug-compatible." In sum, it should be possible to define interfaces with the appropriate level of abstraction.

The group further agreed that the system architecture that will emerge from the process under way by the IVHS AMERICA System Architecture Committee should be strongly endorsed by industry and government, leading to <u>guidelines</u>. Together with what will have been learned from ongoing field tests and products already in the market place by then, we can expect rapid convergence to accepted standards, if there is free flow of information to accomplish this. In particular, data from field tests, and the methodology of evaluation of these field tests, must be made comparable, <u>globally</u>. For this purpose, testbeds should be developed for the evaluation of performance and other characteristics of various pilot systems in common environments.

References

1. Chadwick, D.J., "Factors Bearing on the Issue of International Compatibility for Intelligent Vehicle/Highway systems," The MITRE Corporation, presented at the IVHS System Architecture Workshop at the University of Michigan, October 24-25, 1991.

2. Varaiya, P., "Aspects of IVHS Architecture Design," University of California - Berkeley, presented at the IVHS System Architecture Workshop at the University of Michigan, October 24-25, 1991.

3. Nigel, D.C.W., "Advanced Transport Information systems (ATIS): Should the Early Implementers Design Systems with a Future Proof Architecture?" British Telecom, presented at the IVHS System Architecture Workshop at the University of Michigan, October 24-25, 1991.

4. Rantowich, N., "A Candidate IVHS Systems architecture Process," Hughes Aircraft Company, a paper prepared for the IVHS AMERICA's System Architecture Committee, 1991.

5. Huber, K.M. and Komanecky, "IVHS - What is the Appropriate Level of Compatibility?" AT&T Bell Laboratories, presented at the IVHS System Architecture Workshop at the University of Michigan, October 24-25, 1991.

6. The IVHS America System Architecture Committee has recommended that several competing studies be undertaken to generate workable architectures, from which one or two could be chosen for further development. Prior to this competition would be a study by MITRE of various alternatives. See ("Functional Requirements for Potential IVHS User Services" (draft), 10 Sept 91, MITRE Working Paper, Project No. 3338C)

7. "Government Open Systems Interconnection Profile (GOSIP)," Federal Information Processing Standards Publication 146, August 1988.

Appendix

A Proposal for an IVHS System Architecture Workshop

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Introduction

In recent years we have seen increasing interest in Intelligent Vehicle-Highway systems (IVHS). Experimental, and even production, IVHS systems have begun to appear in Europe and Japan, and some systems are being developed in the North America now as well. Comparison of these systems reveals that each provides important features recognized as part of the "IVHS problem," but none solves the entire problem, whatever that is. What the problem is that needs eventually to be solved is, of course, part of the current dilemma.

Unfortunately, as a variety of partial solutions come into being, each introduces some incompatibility with the others. If we envision an overall solution some day, we also see the need for compatibility at some level, so that travelers moving from one geographic region to another will be able to benefit from the availability of IVHS resources in those regions without undue cost or delay. Unless some attention is paid to the problems of compatibility, early enough to reduce the costs of retrofitting systems because of possible later agreement on "standards," these costs could undercut all later efforts to achieve meaningful compatibility.

The workshop proposed here will explore the problems and opportunities toward achieving compatibility at least in the area of Advanced Traveler Information Systems (ATIS). If some agreements can be reached in this area, while taking into account interfaces with other aspects of IVHS, perhaps further efforts, both within the ATIS domain and in the wider IVHS domain would be made easier and more productive in the future.

The Workshop

The purpose of the workshop would be to explore the feasibility of achieving some level of agreement on functional requirements in the ATIS domain. Specific questions to be discussed would be:

(1) Is it desirable, or even possible, to aim for common functional requirements for an ATIS system for the entire world? For Europe, Japan, and North America, where do most of the current actions occur? Given the different cultures, geography, demography, perceived user requirements, and so on, in these diverse areas, is it realistic to aim at common interfaces?

(2) Is it feasible to take a normative forecasting approach to aim for common functional requirements for an ATIS system on the basis of alternative future IVHS scenarios? Given the comprehensive and uncertain IVHS of the future, of which ATIS is a part, is it practical to design system architectures now that can accommodate most if not all of the future functions?

(3) How necessary is it to achieve compatibility over time? That is, if expanding subsets of ATIS features are introduced which expand IVHS capabilities, how necessary is it that earlier versions continue to function as they did, under new, presumably more capable regimes?

(4) Is it possible to agree on a process which would lead to an accepted set of functional requirements for a geographic region (to be determined under (1) above? How should this process avoid the obvious conflicts of interest that come from existing products already in the field?

(5) What is the appropriate level of compatibility; i.e., can interfaces be specified at some level of abstraction among components of an ATIS system so that any concrete implementation which is consistent with the prescribed interfaces, but which may differ radically within each component from any other system, is acceptable as satisfying the agreed upon "standards"? How can the "hooks" be provided for other subareas of IVHS?

We note that many of the topics listed above were discussed in the excellent paper by N. D. C. Wall and D. H. Williams, "DRIVE Integrated Communications Infrastructure," presented recently at the DRIVE meeting in Brussels. We would recommend to each of the writers that the concepts presented in this paper serve as an example, if not the basis, for their position papers. This will give the workshop an immediate focus for discussion, whether the ideas and recommendations in that paper are adopted or not.

Organization of the workshop

A Program Committee has been established, consisting of Bernard A. Galler (chairman) and Kan Chen of the University of Michigan, Jack Kay (JKH & Associates), Robert Parsons (Parsons & Associates), Nigel Wall (British Telecom Research Labs), and Hironao Kawashima (Keio University). This committee will plan, organize, and conduct the workshop with the assistance of a Local Arrangements Committee. It is the responsibility of the Program Committee to determine the participant list for the workshop, and the writers of the position papers.

About 50 experts will be invited to attend the workshop, at a location convenient and accessible to them. The workshop will last two days, and will be based on invited position papers on each of the five topics outlined above. If there might be more than one view on a specific topic because of identifiable constituencies, more than one author may be invited to write on a specific issue.

The position papers will be distributed to expected attendees in advance for their consideration, and at the workshop there will be a plenary session to introduce all of them and answer preliminary questions. Then the group will break into parallel sessions to discuss each of the topics. On the second day, the groups will present their conclusions, their areas of disagreement, and their recommendations for further activity, for example, by the System Architecture Working Group of IVHS America.

Summaries of the presentations will be prepared by specially designated observers, for publication as a monograph, to be available to the interested public. The monograph will contain the original position papers, plus summaries of the discussions arising from them, and the group's recommendations for the future.

Representation

There should be at least some representation from each of the following constituencies to provide multiple perspectives during the parallel discussions of the principal topics outlined above. The relevant constituencies are:

1) European IVHS experts
2) Asia-Pacific IVHS experts
3) North American IVHS experts
4) U.S. Department of Transportation
5) State and local departments of transportation
6) Academic and non-profit institutions
7) Transportation vehicle vendors
8) Communications equipment and systems vendors
9) Experts on legal, sociological, and political IVHS matters
10) Public transit
11) Heavy vehicle (commercial) experts
12) IVHS America System Architecture Working Group representatives
13) Consultants