Intelligent Transport System Architecture Different Approaches and Future Trends

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Abstract. System Architecture for Intelligent Transport Systems (ITS) has been an active topic across the globe for many years. There are two basic different approaches to its creation and implementation, represented by the European ITS Framework Architecture, called FRAME, and the National ITS Architecture of the USA. Their principal differences lie in the manner and the flexibility of their use. The challenge Europe is facing is based upon the fact that there are many different states with different needs and it is therefore not possible to create a universal ITS architecture suitable for all of them. For this reason, there is framework architecture at the European level from which national or regional architectures can be created by specific states based on their individual requirements. Thus, the situation varies from state to state. On the other hand, the USA has a fixed ITS architecture, the use of which is obligatory if federal financial support for ITS deployment is desired. This paper aims to compare the two approaches and discusses the developments and ongoing activities to support ITS architecture implementation in Europe.

1 Introduction

Today's intelligent transport systems and services are based on the cooperation of subsystems interconnected by potentially different telecommunication technologies and interfaces. The development and deployment of such systems is a complex task that needs extensive preparation in order to meet the desired time schedules of implementation, high standards of operational quality and satisfied customers.

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In other words, according to Bossom & Jesty (2009) when implementing ITS systems, complexity grows with the number of installed systems. This poses a threat to their effectiveness, manageability, maintainability, extendibility and refurbishment over time, and to overall costs. Overcoming the possible problems of having too many incompatible systems, and benefiting from the possible synergies of interoperable systems requires the use of an agreed architecture**.** Using an ITS architecture can save time and money during the system development and deployment thanks to the ability to analyze in advance any possible risks, different scenarios, etc. In this paper we aim to analyze these statements for the various approaches to the formalization of deployment of ITS throughout the world.

2 ITS Architectures in General

The concept of ITS architecture ranges from a relatively simple definition of a single telematics system to a “huge” definition of a complex telematics system described using several viewpoints of the system, together with its deployment plan, process and object-oriented procedures, cost benefit analysis etc. The viewpoints of an ITS architecture are constructed using different perspectives (e.g. functional, physical) and may go into different levels of detail. Beginning with the general point of view, this variety of approaches can be broken down into two basic concepts of an ITS architecture that are used in the ITS domain: high-level and low level ITS architectures (Böhm & Frötscher, 2010).

2.1 High-Level ITS Architectures

High-level ITS architectures are used to provide a description of the functionality and communications needed to supply the services expected by stakeholders from a particular ITS implementation. Within a high-level ITS architecture, the functionality is shown in the form of the "component specifications" required by ITS to implement the services, with the "communication specifications" describing how the links between the "components" will be provided. All of the "specifications" are technology independent and are intended for use as inputs to the procurement part of the overall ITS implementation process.

Making the "specifications" technology-independent gives suppliers the freedom to employ the most appropriate technical solution when tendering, while still complying with the architecture.

This type of ITS architecture is created by (or for) organizations such as national and regional governments, municipalities, research projects, etc. Aside from the FRAME Architecture, the most obvious and widely used example is the US National ITS Architecture.

Creating high-level ITS architectures is a precursor to the creation of low-level (or design) ITS architectures. The "bridge" between them is provided by the component specifications and communications specifications which are used in the procurement process.

2.2 Low-Level ITS Architectures

Low-level ITS architectures are used to describe the detailed design of the components and the communications, which are needed for ITS implementation. These architectures are created as part of the design activity that commences once procurement has been agreed and use the "component specifications" and "communications specifications" as their starting points. The term "components" is used because the functionality described in the specifications may be achieved using either hardware, software, or a combination of the two. The use of particular technologies will almost always form a part of the low-level architecture descriptions.

For many ITS implementations, several low-level ITS architectures may need to be developed. The actual number of these architectures will depend on how many "specifications" have been produced. In simple terms, the creation process for each low-level ITS architecture will be an expansion and refinement of the "component specifications" and "communications specifications" from which the ITS implementation is created.

3 Duality in the Development of High Level ITS Architectures

The need to have agreed ITS architectures was recognized some 20 years ago, in early 1990s.

It was motivated by the rapid research and development of services in the ITS field that needed to work together if they were to be effective. It was clear that it was not efficient to develop separate solutions for every application and that some model principle – an architecture was needed. This need was recognized on both sides of the Atlantic. Whilst the development of the Architectures was carried out separately, there is a commonality of approach. We will describe briefly the US National ITS Architecture and the FRAME (European) models of high level architecture.

3.1 US Approach

According to Sussman (1999) the US DOT, urged on by ITS America, triggered the development of the National ITS Architecture in 1994. The motivation for creating a National ITS Architecture was the need to describe how its various elements or subsystems would communicate, and what functions would be performed by each. A primary purpose was to describe the communications links in order to guide the development of standards, which would in turn ensure national interoperability.

A concern and reason for the development of the ITS architecture was that systems, developed freely around the country, would prevent vehicles going beyond their own regional boundaries from interacting effectively with the infrastructure in other regions. This was a particular concern for the national freight industry, which had visions of carrying 15 or more transponders in their cabs to allow interaction with various infrastructures as they travelled across the country. This was also a concern of the ITS suppliers who wished to sell hardware and software on a large, integrated, national market.

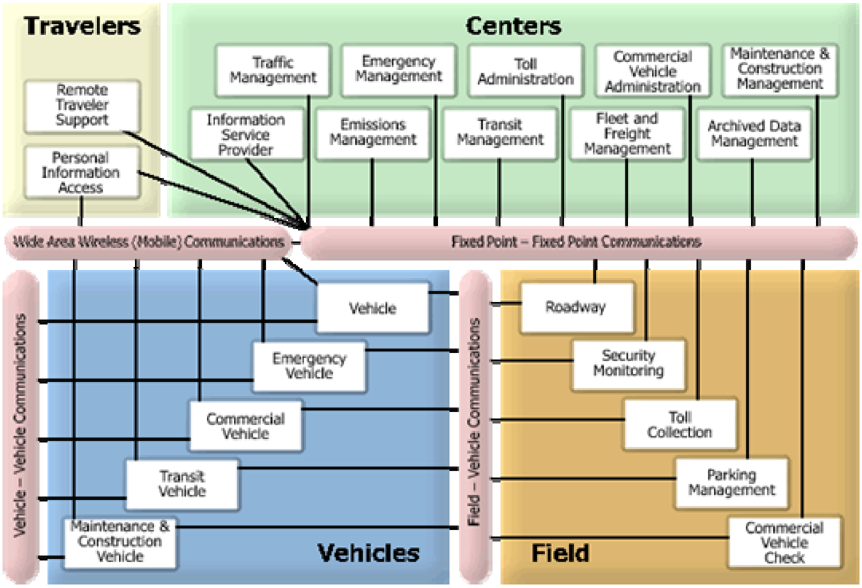

Fig. 1 Physical view of National ITS architecture (source: www.iteris.com)

The first version of the US National ITS Architecture was delivered in 1996 by a consortium under contract to U.S. DoT as a substantial and content-rich set of documents. This architecture makes a major contribution to the definition of the structure of ITS (see Figure 1). Since the architecture has to be maintained in order to stay usable, later versions of the architecture, and the tools for using it, have followed. The current version of the National ITS Architecture is found under 6.1 and is hosted at http://www.iteris.com/itsarch/

3.2 European Approach

After some initial work during Frameworks 2 and 3, in particular by the SATIN Task Force in 1996, the development of the European ITS Framework Architecture started during the 4th Framework Programme of the EC in 1998 with the KAREN project (Keystone Architecture Required for European Networks). This was developed at the request of the High Level Group in response to the need for a single reference platform in Europe, which would provide a basis for the development of ITS products and services throughout the European Union.

The basis for the creation of the architecture was the fact that, due to subsidiarity within EU member states, ITS cannot be covered by a single definitive architecture and thus a framework (meta model) of ITS architecture is needed. As it is framework architecture, its goal is to assist the development of national, regional or even project architectures.

The project produced its final ITS architecture description in a number of deliverables in 2000. Since the creation was an R&D activity, its development could have ended with the KAREN project. However, the ITS Architecture as a framework for the development of ITS systems and services was further promoted by the EC in further FP projects, and continuity was guaranteed by using the same key members of project consortium. During this time the meta-architecture started to be called FRAME (FRamework Architecture Made for Europe). Project succession in FP5 was provided by FRAME-NET and FRAME-S as support activities, and the current project E-FRAME in FP7. E-FRAME aims to include results of cooperative systems projects in the Framework Architecture, and the current version is 4. The FRAME Architecture is now managed by the FRAME Forum, which is made up of representatives from the Ministries of a number of member states.

4 National ITS Architecture

4.1 Content and Processes

The US National ITS Architecture provides a common framework for planning, defining, and integrating intelligent transportation systems. It is a mature product that reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.). The architecture defines:

- The functions (e.g., gathering traffic information or requesting a route) that are required for ITS.
- The physical entities or subsystems where these functions reside (e.g., the field or the vehicle).
- The information flows and data flows that connect these functions and physical subsystems together into an integrated system.

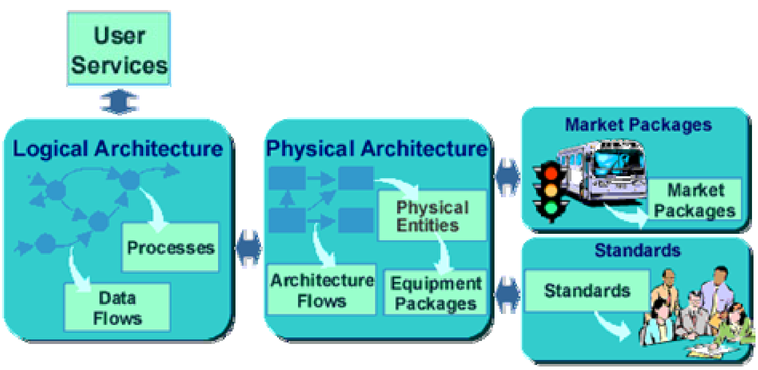

Fig. 2 National ITS Architecture view (source: www.iteris.com)

Figure 2 describes relationships between the logical architecture, physical architecture, implementation, and standards-oriented components of the US National ITS Architecture. User Services describe what the system will do from the user's perspective. A set of requirements covering each of these User Services form the basis for the US National ITS Architecture definition. The User Services entry point leads you to the full set of user service requirements and allows an easy transition between the user service requirements and the components of the architecture that satisfy these requirements.

The Logical Architecture defines the Processes (the activities or functions) that are required to satisfy the User Services. Data Flows identify the information that is shared by the Processes. The Physical Architecture forms a high-level structure around the processes and data flows in the Logical Architecture. The Physical Architecture defines the Physical Entities that make up an integrated ITS. It defines the Architecture Flows that connect the various Physical Entities into integrated systems. Equipment Packages break up the subsystems into deployment-sized pieces. Behind these entry points is the complete definition of the Physical Architecture.

Market Packages represent slices of the Physical Architecture that address specific services like surface street control. A Market Package collects together several different subsystems, equipment packages, terminators, and architecture flows that provide the desired service.

The Logical and Physical Architecture provide a starting point for ITS standards development activities by identifying the applicable architecture flows and data flows to be standardized in the US National ITS Architecture and the way in which the information is exchanged across those interfaces.

4.2 Responsibility and Applicability

The US National ITS Architecture has been designed to be used for the development of consistent "regional architectures", with the aim of facilitating the goal of national interoperability.

The organizations responsible for the "local" deployment should be willing to be consistent to ensure this goal of national interoperability, even if it is more costly to do so. In addition to this, they could see themselves as being constrained in their deployment strategies. The reason for this is the support from the federal budget for projects that are aligned with national ITS architecture.

The U.S. DOT requires the Secretary to ensure conformity with the US National ITS Architecture and Standards via TEA-21 (The Transportation Equity Act for the 21 century, Section 5206 (e)). ITS projects implemented with funds from the highway trust fund, or using federal funds, must conform to these federal rules, otherwise they will not receive the funding.

4.3 Support

The National ITS Architecture is continually supported by the government, the US DoT. Since there is a legal requirement for the use of the US National ITS

Architecture, a team maintains the architecture itself, presents workshops and seminars, checks compliance with the architecture and has developed and provides support for a software tool for the development of compliant local architectures.

The software tool which regions can use to create their own ITS architectures is called Turbo Architecture, and the current version is 4.1. Turbo Architecture is an interactive software application that assists transportation planners and system integrators, both in the public and private sectors, in the development of regional and project architectures using the US National ITS Architecture as a starting point.

5 FRAME Architecture

5.1 Content and Processes

The FRAME Architecture can be used early in the lifecycle both to convert the Stakeholder Aspirations (sometimes called User Requirements for what the ITS implementation should provide) into an ITS Architecture that satisfies them.

The first and core part of the process is the capturing of Stakeholders' Aspirations. These aspirations are simple statements about the services that end users want the ITS implementation to deliver. They can include statements about where

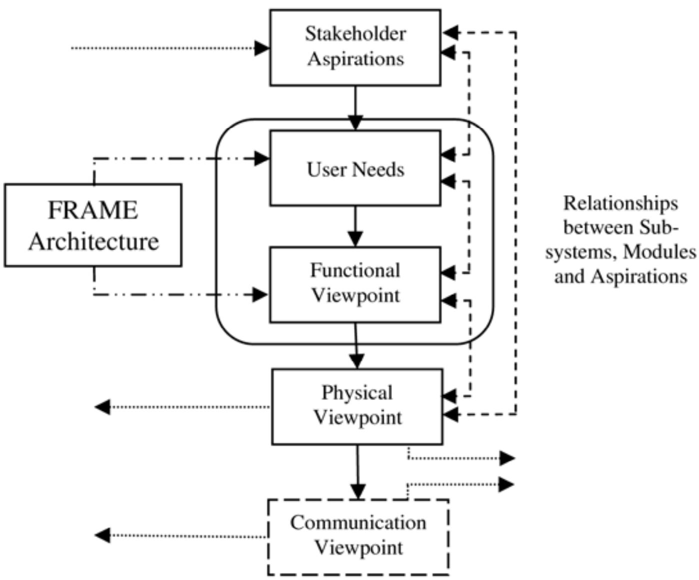

Fig. 3 Process of creating of an ITS Architecture [source: (Bossom & Jesty, 2009)]

and when the services are to be provided, and will be expressed in the stakeholders' own words. Other factors such as availability, ease of access, presentation, reliability, maintainability and, in some instances, cost can also be included in the aspirations.

These stakeholder aspirations are transformed into User Needs – from a formalized set of more than 700 needs covering most possible ITS applications and services.

The next step is to create the functional viewpoint (following the recommendations of [IEEE 1471]) – which defines the necessary functions to fulfill these User Needs. These two items (User Needs and Functional Viewpoint) are covered by the FRAME Architecture. Based on the Functional Viewpoint, but outside of the scope of FRAME, the Physical Viewpoint and subsequent Communication Viewpoint are developed.

5.2 Responsibility and Applicability

A number of European national and regional authorities now have their own national and regional ITS architectures, based on the FRAME Architecture. There have also been a number of EC funded projects that have used it.

The experiences of using the national or regional ITS architectures are mixed, and it is probably too early to draw any final conclusions. The issue is not whether the use of the ITS architecture has been beneficial – in all known cases it has been. Indeed the French Ministry reported that they were able to reduce the development and deployment time for a national speed limit enforcement system by an estimated 6 months.

There has, however, often been a reluctance to take up the use of the ITS architecture voluntarily by engineers outside the core architecture team. The reason for this is currently the subject of speculation, but the fact that the use of high-level system architectures is not normally taught at universities will be one. Fear of something new will be another. A third reason may be that many authorities are not used to making long term plans, since they have to spend all their time "fire-fighting" the latest problem, and there is no perceived immediate need to integrate the resulting systems. It is interesting to note, however, that whist the English national authority does not see a need for a national high-level ITS architecture, a number of English regions and agencies now have, or are creating, their own ITS Architectures independently of each other – all based on the FRAME Architecture.

The new European ITS Action Plan, and the ITS Directive mentions the need for ITS Architecture, though it does not go into any detail, and one can expect the situation to change as a result.

5.3 Support

The creation and maintenance of the FRAME Architecture has so far been carried out in an ad hoc manner. The EC has funded four projects (KAREN, FRAME-S, FRAME-NET and E-FRAME), but there is no mechanism to provide long term "unlimited" support. At the end of the FRAME-S and FRAME-NET projects, the FRAME Forum was set up to provide funding from a number of Member States. The Forum still exists and a revised modus operandi is being planned to take over at the end of the E-FRAME project.

The FRAME Architecture is distributed with 2 basic tools. The first tool is called the "Browsing Tool" and is used for browsing through FRAME architecture to understand how data flows between the various functions. The second tool is called "Selection Tool" and is used for creating sub-sets of the FRAME Architecture for regional, national or project ITS architecture.

6 Comparison of EU and US Approaches

The US National ITS Architecture shows the relationship between physical components, and users choose those components that they need to satisfy their requirements. However, the European ITS Framework Architecture shows the relationship between functions only, and users first choose those that they need to satisfy their requirements, and then make their own decisions as to how they will be allocated to physical components.

The US National ITS Architecture has had continual support totaling about $65M. Meanwhile the European ITS Framework Architecture has had intermittent support totaling around €4.5M since 1998. Whilst the European approach could be considered to be more efficient, there is still a major disparity in their support, which results in perceived differences in both their quality and their ease of use. There is also a major difference in their political backgrounds and their consequential manner of use, which is not always understood by those who stand in judgment.

The use of the US National ITS Architecture is effectively mandatory throughout the USA (unless the region does not want Federal financial support for its ITS deployments!). The Architecture comprises a set of fixed "Market Packages" and "Equipment Packages" that can be put together to fit the requirements of the stakeholders. The Market Packages and Equipment Packages are examples of "real" implementation. The European ITS Framework (FRAME) Architecture has been designed for a set of Member States for whom the concept of subsidiarity must apply. It is for this reason that everything in the FRAME Architecture is optional. This makes the use of the FRAME Architecture extremely flexible. The creator of a bespoke ITS Architecture based on this must understand it. The creation process also takes some time to complete, i.e. a number of days.

It is against this background that the US and FRAME Architectures are compared, and it is not surprising that the FRAME Architecture is sometimes criticized for being (too) difficult to use. However, since it is known that Member States undertake some ITS applications and services in different ways, the flexible nature of the FRAME Architecture will have to remain for the foreseeable future.

7 Usage of High Level ITS Architectures

7.1 Why Is It So Difficult?

In this paper, we only discuss use of high-level architectures and their impact on low-level architectures. Many people find high-level architectures very hard to understand and use. Therefore developers, who want to build the system, tend to create their own high-level architectures based on their own prior knowledge. The difficulty of using predefined, high-level architectures can be illustrated by the following statement (McQueen & McQueen, 1999):

"We have encountered many difficulties when discussing the concept of a regional ITS architecture … maybe it is such an abstract concept that most people do not see enough potential value in it to justify spending the time understanding it … the system architecture concept has been a difficult one to get people to embrace and like. It certainly seems to trouble the majority of people. Even the systems engineering community that adopted the term in system development methodology can get into quite lengthy debates about what it actually means."

7.2 Actual Usage of ITS Architecture in Europe and US

In the EU, the first two national ITS Architectures that claim some degree of compatibility with FRAME were developed by France and Italy. So far they have been used mainly for Case Studies, about which, positive reports have been received. However the French ITS Architecture (ACTIF) has recently been used as the basis for the development of a speed limit enforcement project, and for an ITS Architecture for Singapore. The Italian ITS Architecture (ARTIST) has also started to be used in the National Transport Operative Programme in projects such as ULISSE.

There are two regional and one project ITS Architecture in the UK, with two further ones being considered. Positive results have been reported from the Czech Republic and Hungary, and the FRAME Architecture has been used to some degree in many EC funded projects, in particular VIKING and COOPERS.

In the US, use of National ITS Architecture is mandatory for all projects that have federal funding.

8 Conclusion

Two approaches to the use of high level ITS architectures have been briefly described and compared. The comparison shows the strengths and weaknesses of the two discussed approaches. From our point of view, the main difficulty is to convince system developers and state officials to use it, even though the benefits are described quite clearly. Whilst the use of ITS architecture does require effort and time to fully understand and to design "any" compliant ITS system, even more work (and costs) would be incurred if an ITS Architecture were not used to achieve integrated ITS services.

The concept of ITS Architectures, as implied in the FRAME Architecture, is not well understood. They are neither used regularly by industry, nor are they covered by textbooks and taught in universities. Whilst there are a number of nations and organizations for whom their use is well understood and encouraged, there is another set who are, at best, ambivalent, and at worst refuse to consider their use – the "not invented here" principal, or believe that they go against their company's commercial interests. Part of the problem lies in the use of the term "architecture", which already has a number of seemingly different uses, and thus often invokes mental images of something else.

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