Concept of unifying the data exchange interface in heterogeneous ITS networks

M. SUMILA

WARSAW UNIVERSITY OF TECHNOLOGY, Koszykowa 75, 00–662 Warsaw, Poland
EMAIL: sumila@wt.pw.edu.pl

ABSTRACT

A concept of unifying the communications interface between heterogeneous ITS subsystems was presented in this paper. In its first part, it concentrates on causes for and consequences of having heterogeneous networks. Then it goes to present methods developed to counteract that phenomenon through the seven layer OSI model and the CORBA standard. In latter parts, two data exchange protocols in heterogeneous ITS networks were presented. In the context of their limitations, an original concept was developed using a shared database as a universal communication interface between different ITS systems.

KEYWORDS: Datex2, NTCIP, heterogeneous networks, shared interface

1. Introduction

Looking back at the past 20 years of ITS development, there have been many obstacles and hindrances hampering integration and compatibility of those systems. The most significant barriers included the sheer number of different computer buses and interfaces used for communication as well as reluctance among manufacturers of telematics-based hardware to share information gathered by their systems with external terminals. The net outcome is those systems have island architecture or operate fed by incomplete data. Due to ensuing limitations, ITS administrators are left with little choice but to build their systems out of solutions proposed by one or several associated manufacturers, since there is no other way to assure correct communication between devices and subsystems.

General Directorate for National Roads and Motorways, faced with increasingly serious issues with implementing the National Traffic Management System, decided to introduce an integrated data exchange standard. In author's opinion, this is the right initiative to undertake, nevertheless the data exchange interface needs to be well conceptualised given ICT technology rapidly develops. Otherwise, it could become the bottle-neck of the newly implemented system. In effect, the outcome for the entire system is worse transmission capability using selected systems, limited access to QoS or even complete inability to deliver newly introduced services.

In the following part of this paper, the problem of heterogeneous ITS networks was presented, including attempted and proven solutions using the OSI reference model and the CORBA standard. Two data exchange standards for heterogeneous ITS systems were presented, one currently being promoted by the EU and the other on African continent. In closing parts of the paper, an original solution was exhibited of both the interface and data exchange without use of superior layer as in the aforementioned standards.

2. Heterogeneous ICT networks

The term heterogeneity is an inherent feature of computer and ICT networks. The reason for it is the fact that networks built some time ago are no longer capable to keep with modern demands and

fail to deliver high data exchange speed and/or are not compatible with currently used interfaces, routing/packet switching methods. The end result comes difficult to accept but the existing systems needs to be shut down and replaced. This is especially challenging when the system in question has a critical meaning. Hence new installations are fitted alongside still operating old systems, which would be far too costly to shut down compared to potential benefits.

2.1 Reasons for heterogeneous networks

The other reason for heterogeneity is the innate need for devices of different type and application to communicate (e.g. desktop computers, mobile devices, actuators). They are often different class coming from different manufacturers, who often compete with one another and attempt to seize clients of competitor companies.

The practices whereby a manufacturer tries to lock up its customers into loyalty are common knowledge. Switching to a different manufacturer often entails issues collaboration and data exchange. Ultimately though-from a solely engineering point of view-it is rarely the case a solution exists that would solve a difficult communication problem in a distributed ICT system and at the same time be acceptable from all angles. Similar issues are often dealt with by engineers in different ways and attempts to integrate are known to lead to heterogeneous networks and systems.

ITS systems are by default heterogeneous. The number and diversity of systems demands from designers of national ITS system, to first concentrate on joint and compatible mechanisms of data collection and propagation from subsystems.

2.2. Solving the issue of heterogeneous networks by using the OSI reference model

In the 80's, ISO (including the X.200 as recommended by ITU-T) introduced OSI RM (Open Systems Interconnection Reference Model), an industry wide conceptual model that characterises and standardises internal functions of different communication systems. The developed and introduced data exchange standard, groups communication functions into layers, each of which has a clearly defined function which could not overlap with functions of other layers. This model alone is responsible for making possible to adapt existing solutions (using OSI model) to new kinds of needs and conditions without having to replace the entire network infrastructure. Only the module responsible for modernised network layer had to be replaced. An important milestone was developing the concept of well-known (open) interfaces between individual layers of the OSI model. Those interfaces emulate traditional hardware interfaces through logical layers, which in practice utilise software solutions.

2.3 CORBA standard

The 90's of the last century saw particularly rapid progress in object-oriented techniques and concepts thus rendering the OSI model incapable to guarantee compatibility of built ICT system. Object Management Group (OMG) came up with Common Object Request Broker Architecture (CORBA) standard which was supposed to bring aforesaid issues to an end. Great strength of that standard is object-oriented approach to heterogeneous computer systems and the fact it displaced data exchange interfaces from bottom OSI layers to layers outside of that model.

In general, CORBA acts as an intermediary, abstract layer above the layer where potential data exchange could be taking place.

Objects comprising logical interfaces are described by IDL (Interface Definition Language) which is compiled to a transmission-oriented code. Those objects have their Interoperable Object References (IOR). They normally contain components identified by its integer code among other IP address, program address, information about byte storing convention (big endian, little endian), object number, object type etc. IOR addresses are also used in low-layer data transmission protocols, usually GIOP (General Inter-ORB Protocol) or IIOP (Internet Inter-ORB Protocol).

CORBA became a key element in unification of data exchange interfaces for ITS networks providing a platform for communication between devices and systems from different manufacturers.

3. Attempts to find a common interface for ITS systems

In case of heterogeneous ITS systems, hardware actuators play a key role. They could come in form of different sensors and devices displaying information. Only information feeding elements and controllers (e.g. STOP sign controller for vehicles exceeding permitted weight) need replacing.

3.1 Analysis of low-level solutions

ITS systems are often built based on hardware interfaces. Those solutions use data buses and communications protocols. Their descriptions define type of connection, type of issued signals, data coding method as well as possible applications.

Based on readily available literature, the following protocols could be listed [according to 3]:
- Process automation protocols – 47 standards,
- Industrial control system protocols – 3 standards,
- Building automation protocols – 17 standards,
- Power system automation protocols – 4 standards,
- Automatic meter reading protocols – 6 standards,
- Automobile / Vehicle protocol buses – 12 standards.

From the viewpoint of ITS applications, the above list of standards is indicative of a multitude of solutions arbitrarily chosen and approved by manufacturers of systems and devices. Commitment of a manufacturer to a given standard may be caused by the need to promote proprietary solutions and a making them industry standard. Another important discussion to be had is over maintaining and developing given interface. Hence a decision was made by organisations standardising ITS solutions to walk away from low-level hardware solutions and concentrate instead on creating a data exchange platform on logical layer level operating outside the limitations caused by protocols used by lower OSI layers and communication techniques.

3.2 Solutions dedicated for integrated ITS solutions

Affiliated organisations aiming to develop ITS standards and systems of communication were successful in bringing to the market two "protocols", American – NTCIP and European – Datex2.

NTCIP

Americans have been working on unification of data exchange for ITS networks since the beginning of 90's last century. Efforts to standardise data exchange between ITS devices and systems were undertaken by a Joint Committee made up of the National Electrical Manufacturers Association (NEMA), the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE).

The result came in form of the NTCIP protocol (National Transportation Communications for Intelligent Transportation System Protocol). The name, however, is misleading because NTCIP is in fact a parent standard designed to assure highest possible interoperability and data exchange between traffic control devices coming from different manufacturers. Figure 1 shows an overview of NTCIP infrastructure.
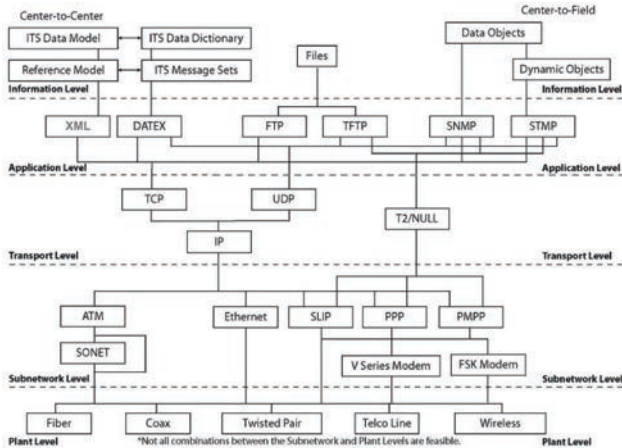

Fig. 1. NTCIP architecture [19]

Note that presented NTCIP architecture uses an abstract layer above the highest OSI layer and in that sense this protocol is convergent with CORBA. Furthermore the protocol is made up of lower levels:
- NTCIP Information Level,
- NTCIP Application Level, application, presentation and session layer of OSI Model,
- NTCIP Transport Level, transportation and network layers of OSI Model,
- NTCIP Subnetwork Level, data link and physical layer of OSI Model,
- NTCIP Plant Level.

In order to make NTCIP work, commonly used standards developed by IETF, W3C and ISO were implemented. Communication is achieved by combining two data streams: user data stream and control data stream. The protocol serves a twofold function, one of which is device-management centre communication, the other concerns communication between ITS centres.

The fact control messages are coded in XML and data exchange model is object-oriented on cross-platform level makes this protocol a highly flexible form of describing transmitted data. In summary, in its current form the NTCIP protocol assures inter-operability between telematics-enabled devices and systems (including description of NTCIP standards):
- Traffic lights – NTCIP 1202,
- Dynamic message signs – NTCIP 1203,
- Environmental sensor stations – NTCIP 1204,
- Closed circuit television cameras - NTCIP 1205,
- Vehicle count stations – NTCIP 1206,
- Freeway ramp meters – NTCIP 1207,
- Video switches – NTCIP 1208,
- Transportation sensor systems – NTCIP 1209,
- Field master stations for traffic signals – NTCIP 1210,
- Transit priority at traffic signals – NTCIP 1211,
- Street lights – NTCIP 1213.

Datex2

Datex2 is a complex standard developed by CEN Technical Committee 278, CEN/TC278, (Road Transport and Traffic Telematics) [4]. Its function is to assure data exchange in ITS networks between traffic surveillance centres and ITS service providers. Built feeding off experiences of OMG and CORBA, Datex2 utilises object-oriented approach and UML language [12] (including that developed by OMG [8]), as a tool to describe the architecture of the standard [1]. Mapping the standard in UML makes possible to accurately reflect both static structures and dynamic which describe different types of interactions. Current iteration of the message exchange platform is based on XML developed by W3C [18]. Documentation available online includes:
- specifications of data model and methodology of object-oriented modelling in UML,
- XML schema generation tool + tool guide for automatic XML code generation by UML model,
- and specifications of the cross-platform model.

What is more, the CASE Enterprise Architect tool developed by Sparx Systems [7] was described as a tool dedicated-although not the only-for modelling dataflow in UML. Figure 2 shows an overview of protocol positioning
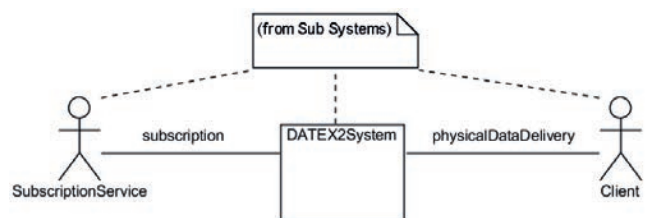

Fig. 2. Basic flow diagram [4]

The figure, represented in UML Use Case diagram, shows an overview of dataflow in an ITS system after introducing the

Datex2 protocol. On this very abstract level two main actors were introduced interacting with the system, whose communication interface is Datex2. The client-in the diagram- denotes an ITS information receiver. It could either the end user or another system operating in Datex2 communication interface. In principle, it is the necessary element facilitating data exchange. There is a general assumption that it is able to receive data about traffic intensity and data necessary for transit route from the system. The other actor is SubscriptionService. The general feeling is it could be either an element integrated with the system or an external service. What is characteristic for this actor is that it catalogues available services and it could operate either on-line or off-line. It it necessary for the data exchange system to function correctly.

Despite such general an overview of dataflow, it already becomes apparent that Datex2 serves as an intermediary element in the dataflow process. On lower levels of interface description, one could come across detailed description of logical organization represented using classes and relationships between packets and classes.

The latest version of the model 2.2 covers:
- Level of service on the network, both in terms of messages for specific situations or as an overall status on the network,
- Travel times,
- Information about all types of incidents and accidents,
- Information about closures, blockages and obstructions,
- Information about road infrastructure status and road works,
- Road weather,
- Information about all kinds of traffic related measurements (speed, flow, occupancy),
- Information about public events with impact on traffic,
- Current settings of variable message signs.

As it stands, the standard has been implemented across Western Europe, Scandinavia and some parts of Central Europe. Among countries where it often being implemented are: Germany, Portugal, United Kingdom and Sweden. Poland has not been covered as of yet, mostly due to concerns that the standard with its enormous potential could be underused and under-utilised.

3.3 Proposed alternative solution

Using one of the aforementioned two protocols as the data exchange interface between ITS devices and subsystems could be called into question. One of the doubts is the level of abstraction where unification of data structure takes place. In both cases, a superior layer is used which requires inputs of unified, processed data which is then used for purposes of telematic services. Similarly in both cases CORBA architecture and XML metalanguage were used to facilitate that. The upshot is that data exchange structures become highly extensive and thus causing major delays. This might weigh down on some services. Especially, when data in question needs to be fed in real-time as opposed to be postprocessed. The effect sought after by those solutions is that system response-here data transmission and response-needs to take no more than the predetermined deadline. Delays beyond that allocated timeslot are defined by RT systems as an error or system failure. The paper [15] attempts to identify criteria for creating data transmission channels

in ITS systems. Because of the aforementioned, applications of the CORBA solutions are very limited because of its "sluggishness".

On the other hand, one should bear in mind that majority of ITS systems uses one or the other type of database, which stores recorded metrics. Figure 4 illustrates an overview of data management architecture.
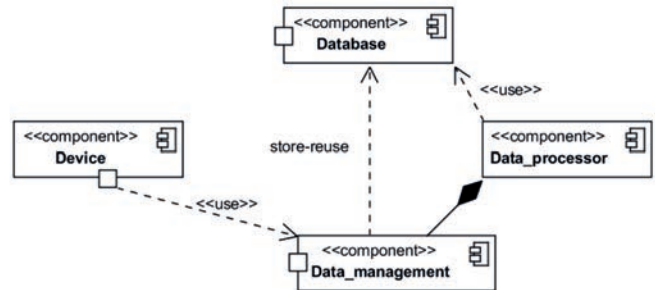

Fig. 4. Architecture of a typical data management system in ITS [own study]

The Data_management module is linked to Data_processor module hence input data fed by devices could be processed and transmitted. The Database component represents any database using any technology storing recorded data. The Device component represents an actuator or terminal unit either collecting or feeding data. In this concept, data circulation is solely internal.

Presented herein solution for unification of data exchange protocol without having to introduce an additional superior protocol is based on an assumption that all ITS subsystems use a shared database. This means that instead of departing from OSI reference model, a sixth layer is introduced whose function is serving as unified interface for all subsystems. In that sense it is fair to say, that a star network is obtained, where the database server is the central node.
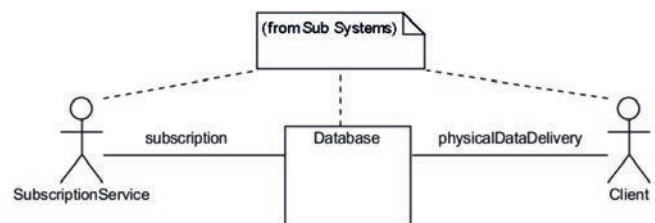

Fig. 5. Data exchange process participants in proposed solution [own study]

Based on Fig. 5 one could assume that the database server is inherently isolated.
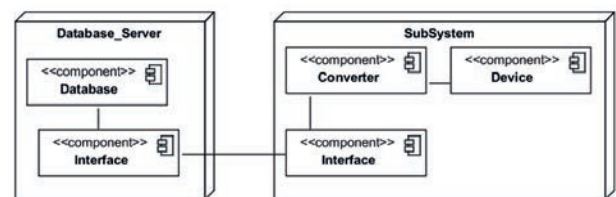

Fig. 6. Nodes of ITS subsystems connected to data-centric systems [own study]

Two nodes in the deployment diagram represent a remote data-centric server and a subsystem with components for converting data to format compatible with the shared database. The Converter component is responsible for message routing into correct query language. The original components architecture would change due to reference to remote knowledge assets. Figure 7 illustrates an extended concept of distributed model
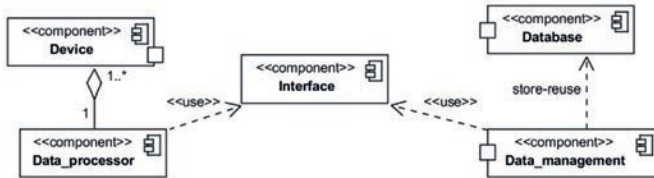

Fig. 7. Modified architecture of a data management system in ITS [own study]

The outcome of that approach is that data gathered from all systems is stored in one place, which can also operate with redundancy and backup all stored data. In case of users with limited access management of data stored in database becomes particularly important. Data processing in case of data-centric solution would definitely improve efficiency and processing speeds due to centralisation of this critical to ITS systems asset.

It is estimated that such an interface would be faster and safer than Datex2 and NTCIP.

4. Conclusion

The issues of connecting devices produced by different manufacturers are relatively well known to telecommunications and data communications engineers. Attempts to induce commitment to proprietary solutions through introduction of original standards were in the past a source of problems with data exchange. They were overcome to a great extant thanks to standardisation of communication interfaces. Despite the fact that majority of ITS systems uses hardware-based solutions, it would be a mistake to seek out unification of the interface/protocol on this level. Substantiating evidence is diversity of transmitted data (data fed by sensors, CCTV cameras) and difficulty to pinpoint a protocol/bus which would focus long-term attention of standardisation organisations. Because of that both Americans and Europeans decided to create solutions enabling heterogeneous devices and networks to be compatible with each other on level of higher OSI layers. Both NTCIP and Datex2 fed off and drew on experiences acquired during development of CORBA. Both solutions use methodology of object-oriented modelling as the right approach to building data exchange and storing architecture. Similarities also include the way transport layer messages are coded. In both cases the choice was to use the XML protocol-a type of metalanguage-which is highly flexible when it comes to describing different informational architectures. This solution seems the only viable one, as far as nation-wide or even international integration is concerned. With regards to a single management centre though, it might prove overly costly to implement and too burdensome for less complex data structures.

For those-more local-applications a better solution would be a data-centric architecture, where a shared database would become an interface between heterogeneous systems. The access, presentation and loads would be controlled by database administrator.

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