SERVICE-ORIENTED INFORMATION LOGISTICS AS SUPPORT TO INTELLIGENT TRANSPORT SERVICES

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ABSTRACT

Today's society is dependent on an increasing volume of transportation services, which contributes to escalating requirements on economy, dependability, safety, and sustainability of applied transportation systems. When dealing with complex transportation systems with long life cycles, maintenance is fundamental to ensure these critical requirements. The increasing requirements and the technological development have also lead to the emerging approach of eMaintenance, which applies innovative Information & Communication Technology (ICT) to achieve effective information logistics for maintenance purposes. This paper describes the role and development of service-oriented eMaintenance solutions to enable intelligent transportation services and some related research efforts within railway and aviation.

1 INTRODUCTION

Today's society is dependent on an increasing volume of transportation of both goods and passengers. This leads to steadily increase in the need of transportation volumes, as well as in requirements on economy, dependability, safety, and sustainability of the transports. To fulfil these needs and requirements, different modes of transportation have to be integrated and both their systems-of-interest (i.e. infrastructure and vehicles), enabling-systems (e.g. traffic control systems, ticketing systems, tracking systems, and computerised maintenance management systems), and enabling services (e.g. information logistics, support, and maintenance) have to be streamlined and integrated to provide timely and effective transportation services.

One example of a national effort intended to achieve this desirable transformation of the transportation sector is the development in Sweden, where the integration of all modes of transportation are intended to be facilitated through the development of the Swedish Transport Agency. This agency is working to achieve good accessibility, high quality, secure and environmentally aware rail, air, sea and road transport. The agency has the overall responsibility for drawing up regulations and ensuring that authorities, companies, organisations and citizens abide by them. [1]

Another important contribution is the technological development. The adaptation of technological advances in the Swedish Armed Forces is one illustrative example of the impact of new technology, as described by the Swedish Defence Material Administration [2] in a prognosis of the coming 25 years. In the future, the Swedish Armed Forces are expected to be a more integrated part of the society that they are expected to protect, than they have been before.

Hence, in order to solve their tasks, the Armed Forces have to cooperate with other national and international authorities, organisations, and companies to a larger extent than before. Another aspect is that there exist many large and complex systems within the Armed Forces. In the future, these systems will be part of a much larger, complex, and dynamic system-of-systems. Simultaneously, individual systems are also becoming smaller (micro and nano scale), highly digitalised, sensor rich, and equipped with Information & Communication Technology (ICT). Another change is that unmanned systems (e.g. Unmanned Aerial Vehicle, UAV) will have an increasing role to play.

One example of a national technological effort in Sweden that reflects the scenario outlined above is the development of a network-based defence, which is coordinated with agencies for civil security (see e.g. [3, 4]). The origin of this project was the task of the Armed Forces to integrate all of its service branches (i.e. Army, Air Force and Navy), while it later expanded to the integration with the agencies for civil security (e.g. the National Rescue Services Board, the Swedish Coast Guard, and the National Police Authorities). This information infrastructure is a valuable complement to the Swedish Government's ambition to create common principles of electronic data exchange between all governmental agencies, which should cover the content taxonomy.

As outlined above, one important contribution to the desired transformation of the transport sector is the research, development and use of intelligent transport services and systems. In order to achieve intelligent transportation services, information logistics is one fundamental enabling service that can be realised through enabling systems based on new and innovative ICT. The main aim of information logistics is to provide just-in-time information to targeted users and optimization of the information supply process, i.e. making the right information available at the right time and at the right point of location [5, 6]. Information logistic services need to deal with: I) time management, which addresses 'when to deliver'; II) content management, which refers to 'what to deliver'; III) communication management, which refers to 'how to deliver'; and IV) context management, which addresses 'where and why to deliver' [5, 6].

When dealing with transportation systems that are complex and have long life cycles, one critical application of information logistics and ICT is for maintenance purposes, which often are referred to as eMaintenance. One view of eMaintenance is the integration of all necessary ICT-based tools for optimization of costs and improvements of productivity through utilization of Web services [7, 8]. This view can be considered as a system-oriented approach to eMaintenance, where Web services technology is used to facilitate integration of information sources that contain maintenance-relevant content.

There are also service-oriented approaches to eMaintenance that deal with information logistics and information services as support to maintenance through the adaptation of a Service-Oriented Architecture (SOA), see e.g. [9].

To achieve proper information logistic solutions, a combined approach that deals with both systems and services is required. However, most efforts seems emphasise the system part and somewhat miss the service part. This is highly unfortunate since the services are the reason that any system should exists. On the other hand, innovative systems may results in new and unknown services; cf. the Kano model and its inclusion of known and unknown requirements [10].

This paper describes the role and development of service-oriented eMaintenance solutions to enable intelligent transportation services and some related research efforts within railway and aviation.

2 INTELLIGENT TRANSPORT SERVICES AND SYSTEMS

From a lifecycle perspective a system might be viewed as a system-of-interest or as an enabling-system. A system-of-interest is a system whose lifecycle is under consideration within a given context, while an enabling-system is a system that complements a system-of-interest during its lifecycle stages, but does not necessarily contribute directly to its function during operation [11]. Analogously, a service might from a lifecycle perspective also be categorised as a service-of-interest or as an enabling-service, since a service is a set of functions offered to a user by an organisation [12]. By this convention, transportation is a service-of-interest, while travelling booking is one example of an enabling-service.

When regarding transportation as a service-of-interest, the mode of transportation is secondary and depends upon the context of the service consumer, as illustrated in Figure 1. This context is affected by available resources (e.g. time and money), capabilities of the transportation systems (e.g. speed and accessibility) and state of the surrounding environment (e.g. accidents and weather conditions). One traditional use of travelling booking as an enabling service is the advance reservation of a trip through a travelling agent. In this case, the travelling agent provides some type of “intelligence” by combining information available from different sources in order to provide a transportation service that meets the requirements of the traveller. The booking service is normally provided before the trip is initiated, but can also be adapted to changing traveller requirement during the trip (as long as the changes occur during opening hours).

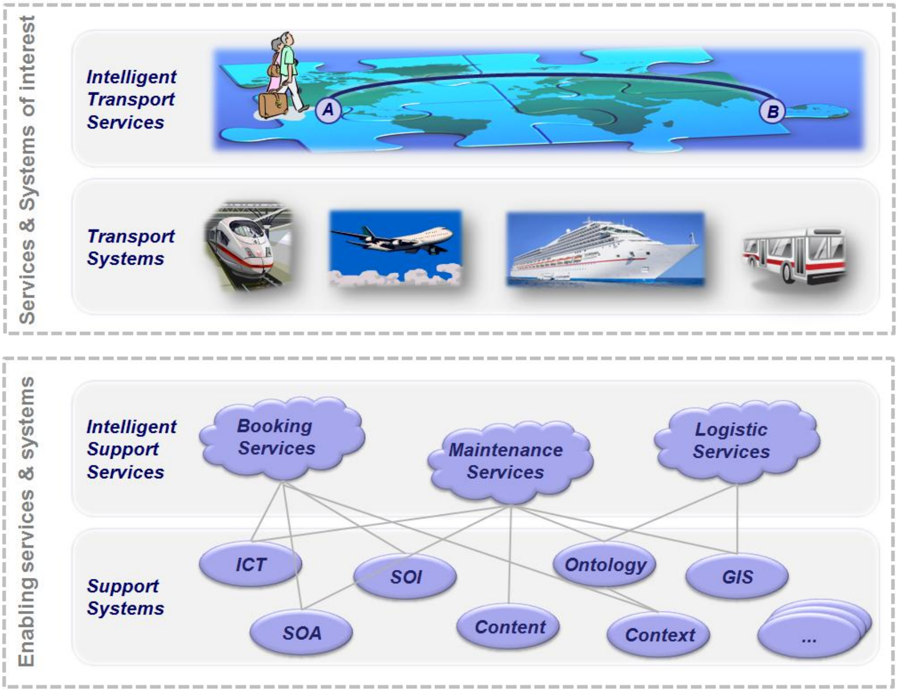

Figure 1 - Relation between systems of interest and enabling systems within the context of intelligent transport systems

Another category of enabling-services is maintenance-related, which can be used to provide the service consumer information related to maintenance and adapted to the consumer's current situation and needs. Maintenance-related information can be used to increase the effectiveness and efficiency of the transport services and system, but also to provide the consumer of the transport services situation-adapted information. For example, information about scheduled maintenance activities on an item within a transport system, e.g. vehicle and rail, can be used within the maintenance process to enable opportunistic maintenance in order to reduce the negative impact on current or planned transports as much as possible. Simultaneously, the same information can be correlated to spatial data in order to provide better decision-support for a route planning service aimed at the consumer of the transport service. Hence, the provision of information services can be considered as essential enabling-services that complement the transport services and contribute to increased satisfaction of the service consumer.

The two examples of enabling-services described above illustrates the contribution of human intelligence, which may be defined as a mental quality that consists of the abilities to learn from experience, adapt to new situations, understand and handle abstract concepts, and use knowledge to manipulate one's environment. Artificial Intelligence (AI), on the other hand, may be defined as the ability of a machine to perform tasks thought to require human intelligence, which is frequently applied to the development of systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalise, or learn from past experience. See [13] for further descriptions of these definitions of intelligence.

Hence, intelligent transport services and systems should, among other things, be able to adapt to new situations. However, this ability requires information input that is received from enabling services and systems, which in turn also should be intelligent. The required intelligence will probably always be a combination of human and artificial intelligence, even though the latter part often is in focus since it is expected to increase in importance in the future.

One important feature of the required intelligence is the ability to make a stratification of service consumers according to their need to access information, their role, hardware and software costs, and security concerns. This stratification of consumers can be based on their network interaction and be distinguished in different dimensions, e.g. based on: the degree of required access (including both the number of participants in the operational function and the variety of data required); the security requirements; and the timeliness (or time criticality of the required information support). These criteria may be used to establish four basic types of network interaction, e.g. specialised interaction; ubiquitous interaction; secure interaction; and real-time interaction (see Figure 2 and [14]).

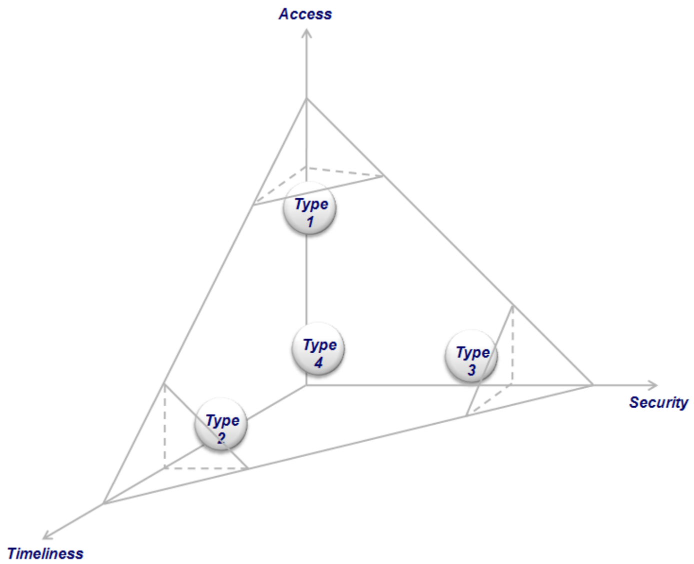

Figure 2 – Service interaction dimensions and types, adapted from [14]

Specialised interaction involves requirements that are not as extreme as for the other three types. The requirements for access to information vary with the role and its information context. As the level of access, timeliness, and security approaches zero, the need for any form of network disappears.

Ubiquitous interaction often affects a large numbers of organisations, e.g. as support to resource management activities and supply functions, along with certain transportations that requires an orchestration of several modes of transportation, e.g. long distance travel. In general, the multiple participants in the supported travel require similar access to data and information on all aspects of the travel available on the federated network.

Secure interaction is related to roles that require that both activities and information are secure, which puts unique demands on the network for interactions among roles and the information exchanged to be secured both physically and electronically. Most services related civil security agencies involved in transportation require this kind of interaction, e.g. police and ambulance.

Real-time interaction is related to roles that require information support that is usually extremely time-sensitive, e.g. drivers of vehicles and traffic control personnel. Another example is the transportation of highly hazardous materials that require that very few participants have access to critical real-time data and are able to share that data among all involved roles, even when network connections and nodes have failed.

3 ENABLING SERVICES AND SYSTEMS

In order to provide intelligent transport services there is a need of underlying enabling-services, e.g. maintenance, logistics and support.

The provision of maintenance services to various stakeholders, e.g. internal users and external customers, is highly dependent on enabling-services that ensure the fulfilment of defined requirements and thereby achieve customer satisfaction. These enabling-services aim at support to maintenance.

Maintenance support addresses all resources required to maintain a system, under a given maintenance concept and guided by a maintenance policy. The required resources include human resources, support equipment, materials and spare parts, maintenance facilities, documentation, information and maintenance information systems [15]. In this context, information management is essential in order to enable the provision of relevant, appropriate, complete, valid, and timely support in the form of information throughout the system's whole lifecycle [11]. Managing information relies on corresponding information logistics.

Information logistics aims to provide just-in-time information to targeted users and optimization of the information supply process, i.e. making the right information available at the right time and at the right point of location [5, 6]. Also in the context of maintenance of complex technical systems, e.g. intelligent transport systems, with long lifecycles the importance of appropriate information logistics is emphasised (see [16, 17, 18]). Here, it should be noted that the life of most services are much shorter than that of the system, which makes it beneficial to have a service-orientation and a high level of intelligence to adapt the services to new and emerging requirements.

Today, the establishment of efficient and effective information logistics is highly dependent on the utilisation of Information and Communication Technology (ICT). The development of ICT-based solutions should consider three essential aspects: architecture, infrastructure and content ontology [9]. The architecture of a solution involves the description of the solution's inherent elements, the interactions between the elements, their composition guided by patterns and constraints on those patterns [19, 20]. The infrastructure can be considered as the platform that aims to provide features for the production environment for a solution. The content refers to the any type of data and information, which are managed by the solution through the underlying infrastructure. The content is used to enable communication in terms of the transfer of messages through a dynamic provisioning of channels and medias for transmission [21, 22], see Figure 3.

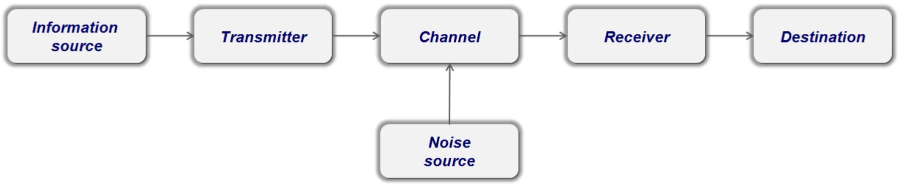

Figure 3 – A model of communication, adapted from [22]

As within eMaintenance, one approach to define a software architecture is based on a service-orientation. Service-Oriented Architecture (SOA) presents a vision of a world where resources are cleanly portioned and consistently represented [23]. SOA is gaining momentum worldwide by promising agility, mobility, interoperability, reuse and better alignment with business objectives [23, 24]. In the context of software architecture, SOA represents a model where business logic is de-composed into smaller elements that can be distributed [23]. One of the benefits of such elements is that they are autonomous and can be individually distributed [23, 24]. Another benefit is that these elements are unified by the term service, in order to reduce their dependency on underlying technology and emphasize their target, i.e. the business processes [23, 24]. Furthermore, the Organization for Advanced Standards for Information Society (OASIS) describes SOA as a collection of best practices, principles and patterns related to service-aware, enterprise-level, distributed computing [25]. SOA-related standardization efforts at OASIS focus on workflows, translation coordination, orchestration, collaboration, loose coupling, business process modelling and other concepts that support agile computing (OASIS, 2008). Hence, service-orientation might be considered as an architectural design philosophy that facilitates encapsulation of business logic in an artefact called service. The establishment of SOA-based solutions requires underlying infrastructure that supports a service-oriented approach.

Service-Oriented Infrastructure (SOI) can be considered as a set of technologies and tools that are required to meet needs and requirements when services, according to SOA, are developed, implemented and managed in a solution [23, 25, 26]. It can be concluded that SOA, with support of SOI, aims to facilitate integration of ICT-based service solutions. The integration of services in a solution enables information sharing, which in return results in efficiency and flexibility in the process of service delivery to the service consumer [27].

4 SOME RELATED RESEARCH EFFORTS

There are several ongoing research efforts that provide contributions that are relevant and can be utilised within the domain of intelligent transport services and systems. Some major contributions are provided by the participants in the collaboration centre named ProcessIT Innovations at Luleå University of Technology [28]. One of the centre's latest research proposals aims to investigate new methodologies and technologies that support an efficient development of embedded lightweight mobile autonomous and real-time services for integration of service-oriented and process-oriented solutions [29]. This planned research combines scientific and disciplinary aspects and focuses on methodologies and technologies that address: formal tools for efficient real-time software design; extreme low-power lightweight embedded system; mobile and wireless communications to enable efficient enterprise networks; context-aware service middleware; value chain information security design; stakeholder driven services - Living labs; Multi-dimensional (area, amplitude, time and phase) data generation; sensor and data fusion; information logistics; context driven adaptation; model-based signal processing and control; and brain-inspired decision models, see Figure 4.

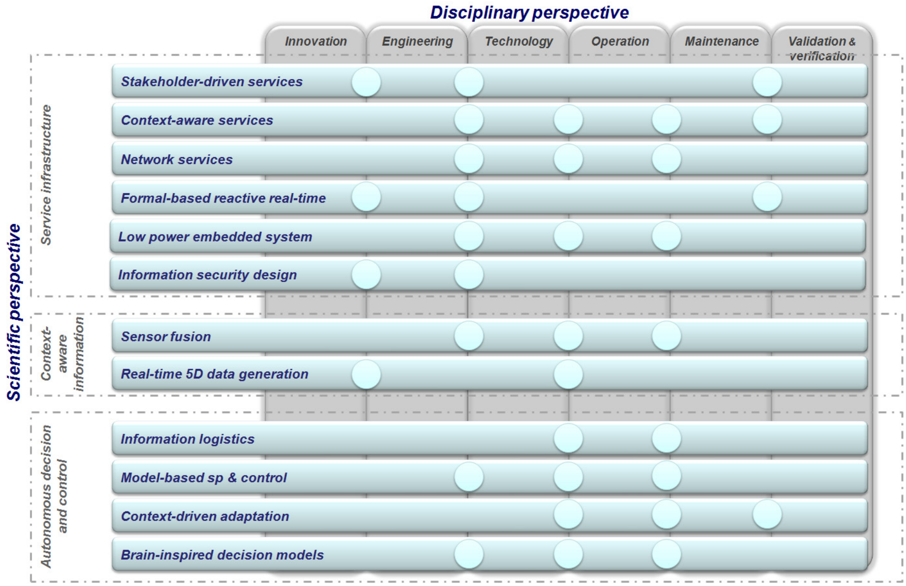

Figure 4 – Relationship between scientific and disciplinary perspective in C-MARS, adapted from (C-MARS, 2009)

In the context of intelligent transport services and systems, the contributions from this kind of research can be utilised to provide intelligent ICT-based information services in order to increase the overall systems performance and thereby achieve satisfaction of the service consumer.

5 DISCUSSION AND CONCLUSIONS

In Sweden there is a new Swedish Transport Agency, which is working to achieve good accessibility, high quality, secure and environmentally aware rail, air, sea and road transport. The agency has the overall responsibility for drawing up regulations and ensuring that authorities, companies, organisations and citizens abide by them. Therefore, there will be laws, regulations, development of transportation systems and services, as well as related research that will stimulate the integration of different modes of transportation.

Simultaneously, the Swedish Government has the ambition to create common principles for electronic information exchange between all government agencies. Hence, there will be an alignment of applied content format and ontology, which will provide an increased possibility to integrate different information sources useful for transportation purposes. In addition, there is a development of a national networked-based defence, which will be integrated with agencies for civil security. Hence, information infrastructures and information architectures on a national level will also be available. Together, these national ventures enforce a national network-based transportation system, which by use of new and innovative service-oriented ICT can provide intelligent transportation services at a national level.

At a national level, information exchange in the context of intelligent transport services and systems the information logistics is essential, since information logistics addresses the aspects of when to deliver; what to deliver; how to deliver; and where and why to deliver. The establishment of information logistics based on SOA and SOI increases the adaptivity of the inherent information services and enables the transportation system's capability to provide intelligent services that are context-aware and situation-aware by combining information available from different sources in order to meet the requirements of the transport system stakeholders.

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