Integrating the individual vehicle in the transport system using open services in a distributed systems architecture

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Abstract: Road traffic management has traditionally been targeted through control and monitoring of the flow of vehicles, using the same measures towards all vehicles. As vehicles can have very different capabilities and profiles, it is however desired to use different control strategies towards the individual vehicles to meet the environmental, safety and efficiency targets for the future. SMARTFREIGHT has developed a holistic control and monitoring tool for managing the traffic, and individual vehicles in particular. The individual vehicle is integrated with the traffic management and freight distribution management centers by using open service interfaces for an interoperable information exchange between distributed systems across a heterogeneous wireless infrastructure. SMARTFREIGHT realized and successfully demonstrated this integration in its final event in Trondheim.

1 Introduction

Transport is a significant contributor to some of the major global challenges we face today. About 25% of EU's greenhouse gas emission in 2008 was due to transport, where road transport is responsible for 70% of this [EEA11], while 34.500 people were killed on EU roads in 2009 [EC 11a]. In addition, traffic congestion costs Europe about 1% of Gross Domestic Product (GDP) every year [EC 11b], illustrating the importance of improving future transport solutions.

The traffic management functions and systems of today are not able to identify, monitor and control individual vehicles based on their characteristics (e.g. type of vehicle, engine class, propulsion technology, and carried cargo). This is mainly due to the lack of communication possibilities with the individual vehicles in the traffic, but also due to lack of information about each of the vehicles, such as information about their environmental profiles, their destinations (transport plans) and their carried cargo in terms of freight vehicles. Current traffic management addresses traffic flows in general, and equal instructions are provided by traffic signs or through radio broadcasts to all vehicles on the road or in an area. By not targeting the individual vehicle in traffic, highly polluting vehicles can drive in environmental sensitive areas, and dangerous cargo can without any restrictions be transported in areas with different safety risks like crowded urban areas and tunnels.

New emerging information and communication technologies (ICT) brings along new possibilities within the concept of Intelligent Transport Systems (ITS). Short and medium ranged communication technologies like DSRC (Dedicated Short-Range Communication as specified by the European Committee for Standardization (CEN)) [CEN03], which today mainly is used in automatic tolling systems, and the new WiFi amendment for mobility (i.e. IEEE 802.11p), along with long range cellular systems (e.g. 2G and 3G technologies) enable a continuous connected vehicle for information exchange with roadside equipment (RSE) and traffic management centers. These communication technologies offer capabilities to a diverse of ITS services, among others the possibility for more individualized traffic management. The implementation of such transport services are guided by the standardization organizations ISO and ETSI through their communication architectures Communications Access for Land Mobiles (CALM) [ISO10] and European Communication Architecture (ECA) [ETS10], respectively, both which are results of work committed in several European research projects. One of these projects are CVIS [1] that implemented the CALM architecture for interaction between distributed systems such as central systems, personal devices, vehicle systems and roadside systems [A$^+$07].

In the European research project SMARTFREIGHT [2], the CALM and ECA architectures, along with the CVIS implementations, are taken further by developing services that integrates the individual vehicle with both the traffic management center and its freight distribution center [3]. The different systems were integrated by following the transport service development methodology as described by the ARKTRANS framework [NWMV09], which ensures holistic and generic services for usability across a range of different European city requirements with respect to traffic management and ICT infrastructure. The distributed architecture and open services proved to be a good foundation when implementing and demonstrating the vehicle integration at the final SMARTFREIGHT event in Trondheim, Norway.

The rest of the paper is organized as follows; Section 2 presents the knowledge, which the solutions presented in this paper rest on, Section 3 presents how the vehicle is part of the distributed systems architecture in SMARTFREIGHT, and Section 4 describes the access control use case used for testing the approach. Finally, Section 5 concludes the paper.

2 Background

The overall objective of SMARTFREIGHT was to develop and demonstrate generic technology that can benefit the society by making urban freight transport more efficient, environmentally friendly and safe. The more detailed objective was to address new traffic management measures towards individual freight vehicles.

The SMARTFREIGHT objectives meets the transportation challenges stated early in the

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[1] CVIS - Cooperative Vehicle-Infrastructure Systems (EC FP6). http://www.cvisproject.org.

[2] SMARTFREIGHT - Smart Freight Transport in Urban Areas (EC FP7). http://www.smartfreight.info.

[3] SMARTFREIGHT's focus was on freight vehicles in the urban area, for more efficient, safe and environmental-friendly behavior

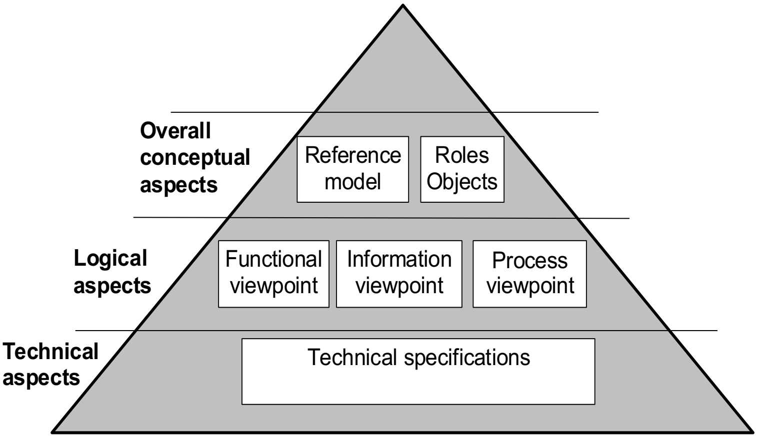

Figure 1: The ARKTRANS content

introduction, and along with the user needs identified through stakeholder consultations (see Section 3.1, the solution presented in this paper has a high problem relevance. The methodology followed in the work to reach the objectives has been on using the process stated as Design Science[4] [HMP04]. The solution is build on using open ICT services, with an emphasis on the interoperability between distributed systems in a heterogeneous communication environment. To obtain this, the SMARTFREIGHT work was rooted on the work made in the CVIS project, which lead to the ETSI and ISO standards on communication architectures for distributed ITS systems. This background knowledge is described in some more detail in the following sub sections.

2.1 ARKTRANS

The transport sector consists of several communicating actors. The objective of the Norwegian ITS architecture ARKTRANS is to gain interoperability when an actor exchanges information with other actors. This is achieved by breaking the transport sector into domains, each with a responsible role, and a set of necessary functions. The functions are further arranged into processes that identifies the required interactions between the different roles. The roles, overall functions and processes are all described by ARKTRANS. Figure 1 shows the ARKTRANS content where the content is gouged into conceptual, logical and technical aspects. The technical specifications are not thorough described – partially due to the focus on implementation independence.

Using ARKTRANS as basis for defining the ITS services in SMARTFREIGHT has pro-

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[4] The SMARTFREIGHT work is founded on the transportation challenges of today, and by using established knowledge, innovative solutions are established in an iterative process with development and evaluation.

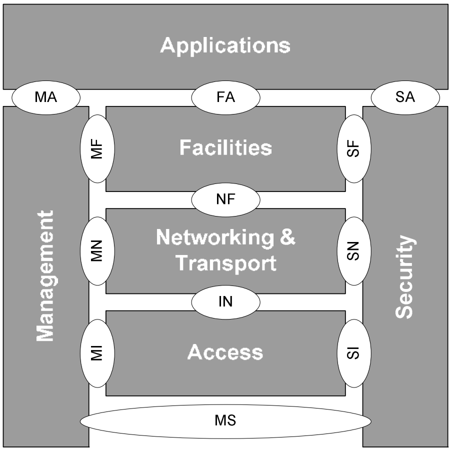

Figure 2: The layered ITS reference architecture [ETS10]

vided holistic, generic and interoperable ITS solutions. However, to accommodate new requirements from the vehicle-to-infrastructure interactions, new and more detailed functionality, processes and information models were defined by SMARTFREIGHT and included in ARKTRANS.

2.2 Distributed Communication Architecture for ITS

The communication architecture, as standardized within both ETSI and ISO, the ECA and CALM, respectively, is based upon a layered reference architecture, which is comparable to the original OSI protocol stack. The reference architecture, shown in Figure 2, defines how ITS services are related to different transport, network and access protocols depending on their communication requirements[5]. Various access technologies like cellular 2G and 3G systems, infra-red (IR), and medium range 5 GHz communication are supported and their use are described in a series of ISO standards from TC204 WG16 [ISO]. One important part of the reference architecture is the management and security support, added as vertical layers. The management layer handles i.a. ITS service advertisements and application lifecycle management, while the security layer handles i.a. authentication, authorization, and certificate management.

ITS systems following the reference architecture interact for information exchange and cooperation; back-end systems (e.g. traffic management systems), handheld personal devices, in-vehicle systems, and roadside systems can thus interact in an ITS domain where ITS routers (i.e. Figure 2 without the Facilities and Applications layer) enable a peer-to-peer communication network. Interaction with external systems (i.e. systems not fol-

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[5] The reference architecture is described in more detail in both [ETS10] and [ISO10].

lowing the ITS reference architecture) is handled by ITS gateways [6]. There will typically be many existing services, also services outside the ITS domain, that will interact with systems within the ITS domain. E.g. traffic management and freight distribution centers will have existing traffic and planning services that will co-exist and co-operate with new ITS services, while the vehicle systems must interact with proprietary in-vehicle networks and sensors (e.g. statuses on vehicle components like brakes, engine, etc.). ITS gateways will in such scenarios sustain interoperability with legacy and proprietary systems and networks.

2.3 The Open CVIS Application Framework

The research project CVIS was the first to implement the distributed communication architecture, and developed several communication services, as well as other facility services (e.g. distributed directory service, application lifecycle management service, etc.), to serve end-user ITS applications. These services were bundled within the OSGi framework and made available from there. The facility services have made it easier for application developers to develop new ITS services [B$^+$07, A$^+$07].

The main communication service implemented by CVIS is the CALM Manager service. The CALM Manager handles application requirements and maps these with the availability of the different communication interfaces. E.g. a latency critical application would use a short-range communication interface like CALM M5 instead of CALM 3G.

3 The SMARTFREIGHT Distributed System

The distributed communication architecture, along with the facility services implemented by CVIS, have provided an infrastructure of interconnected systems. SMARTFREIGHT has on top of this infrastructure developed open services that provide information interoperability between the systems, in-vehicle systems included.

3.1 User Needs

A user needs review and stakeholder consultations were undertaken to identify generic user needs and to quantify and qualify the needs for information exchange between urban traffic management systems (UTMS), freight distribution management systems (FDMS) and individual freight vehicles [M$^+$08]. Both the UTMS and FDMS identified the need to exchange information with the individual vehicle (e.g. to give directed information and instructions such as dynamic route guidance). The study in Dublin confirmed that the

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[6] Gateway services are part of the Facility layer. Dedicated ITS gateways will thus not need the Application layer.

identified user needs to a large extent cover the requirements that the freight operators have. The user needs were also discussed with the local reference group in both Winchester and Trondheim, and the representatives for both the operators and the city authorities confirmed the user needs collected.

Some UTMS (e.g. Dublin, London) restrict heavy goods vehicle (HGV) access and need enforcement systems to do this. Enforcement systems typically employ automatic license plate recognition (ALPR) cameras and a database containing vehicle registration details for exempt users or for registered users who must pay a fee. The access control solution presented in this paper is a more flexible mechanism to handle vehicle accesses, a solution in where representatives from the road authorities in Trondheim were consulted and involved in during the work.

3.2 SMARTFREIGHT Concepts and Open Services

All cities and regions are different, and the traffic management strategies towards freight distributions also differ. Hence, the cities should be allowed to define their traffic management policies depending on local needs. To support the diversity among cities, SMARTFREIGHT defined a set of generic concepts, which by using these concepts in the information exchange, different traffic management strategies can be handled in a common and generic way [NM11]. Related to the use case presented in Section 4 is the concept *Controlled Area*. It is an area or section of the transportation network that is monitored or has a priority or access restriction schemes (e.g. tunnels, green city areas and parking areas). Other concepts related to the transportation network are *Transportation Network Resource* and *Checkpoints*.

In addition, there are concepts supporting the traffic management, like the *Access and Priority Assignment (APA) policy* (i.e. a formal definition of the traffic management rules for a Controlled Area) and *Access and Priority Offer (APO)* (i.e. priority and access right assigned to an individual vehicle for a Controlled Area). Such area policies will have static rules for normal traffic conditions, while there also might be dynamic rules in case of traffic situations that require specific measures. The access rights and priorities are assigned based on vehicle properties, which arrange for control and monitoring of individual vehicles.

The concepts arrange for generic services that cover many purposes. The concepts are decoupled from underlying communication technology and implementations. The generic services are defined with APIs for information exchange between the systems (see Section 3.3), and to make the solutions transferable across different ICT infrastructures. These APIs also ease the integration of the new services into existing UTMS and FDMS services. Table 1 shows some of the service interfaces defined for interaction with the vehicle.

Table 1: Service APIs for vehicle interaction

Service interface	**APIs provided**
Resource Management	Req. for/Prov. of resource booking
	Req. for/Prov. of resource booking cancelation or update
	Req. for/Prov. of info on resource availability
Traffic Management	Req. for/Prov. of city/regional policy
	Req. for/Prov. of notifications
	Req. for/Prov. of network and traffic situation information
Vehicle Reporting	Req. for/Prov. of tracking info
	Req. for/Prov. of vehicle info
	Req. for/Prov. of entry/exit notification for controlled area
	Req. for/Prov. of vehicle (safety) status
Route guidance	Req. for/Prov. of route guidance
Goods	Req. for/Prov. of goods tracking
	Req. for/Prov. off gods status
	Req. for/Prov. of goods info

3.3 SMARTFREIGHT System Components

Figur 3 shows the SMARTFREIGHT system components and the communication paths between the system components (strong lines). The vehicle consists of an in-vehicle host and router[7] (i.e. On-Board Equipment (OBE)) and connected cargo (with On-Goods Equipment (OGE)). The in-vehicle host encompasses an application runtime environment[8] for the installed applications. The vehicle communicates with the FDMS and UTMS through service interfaces from Table 1. Both existing and new UTMS and FDMS services can use these service interfaces to take advantage of the SMARTFREIGHT functionality for using the possibilities the new information acquiring brings along.

Roadside stations (i.e. RSE) can function both as a communication relay and as a distributed UTMS; one example is the local control and monitoring in the access control use case in Section 4. Most SMARTFREIGHT scenarios only require existing communication infrastructure like cellular systems as information bearers, while RSEs provide new means for local interaction with vehicles. RSEs use short-range communication technology, which have a limited range, but the higher bandwidth and lower latency enable new possibilities for local control and monitoring of individual vehicles. The Control Centre (CC) and Host Management Centre (HMC), which distributes and manages applications, are included for a complete picture[9].

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[7] The mobile router uses the IPv6 Network Mobility (NEMO) for global and ubiquitous connectivity with improved vehicle and session mobility.

[8] The application runtime environment is OSGi with necessary facility services.

[9] Refer to [B+07] for more details on the CC and HMC.

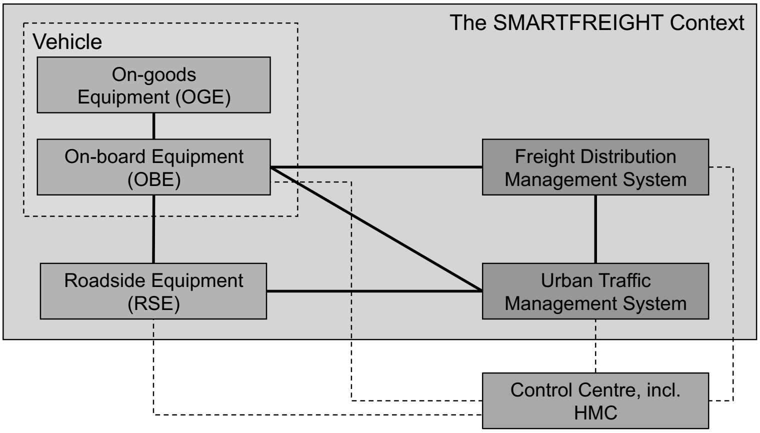

Figure 3: SMARTFREIGHT system component architecture

4 Use Case: Access Control

Vehicle access control can either be performed centrally, distributed, or somewhere in between. The degree of distribution depends on where the individual vehicles' properties are processed and compared to the access policy requirements. Central solutions require a lot of signaling if individual vehicles' properties are taken into consideration (all vehicles will then send their properties for central processing), while the distributed approach is more scalable with respect to processing and communication (a broadcast of the access policy enables distributed processing within the OBEs). The distributed approach also preserves the privacy. As far as we know, SMARTFREIGHT is the first project to specify and implement a complete distributed access control.

4.1 Distributed Access Control

The distributed access control can be used to control and monitor any Controlled Area. It is based on an access policy (i.e. the APA policy) where the traffic management have defined requirements for any vehicle entrance. Figure 4 shows the information elements for the access policy in an UML representation. The figure shows that the entrance will depend on both vehicle properties and timing, while the vehicle can be obligated to report its activities. The reporting is essential for monitoring vehicles' activities (e.g. for statistics or enforcement). Note that identification of vehicles can also be obtained through ALPR cameras. Since each vehicle compares the general access rules with its own vehicle properties (automatically in the OBE), the traffic management is able to reach the individual vehicles with a generic measure. The drivers are then informed on-screen about restrictions and accesses that apply to their specific vehicle; they do not need to be aware of the

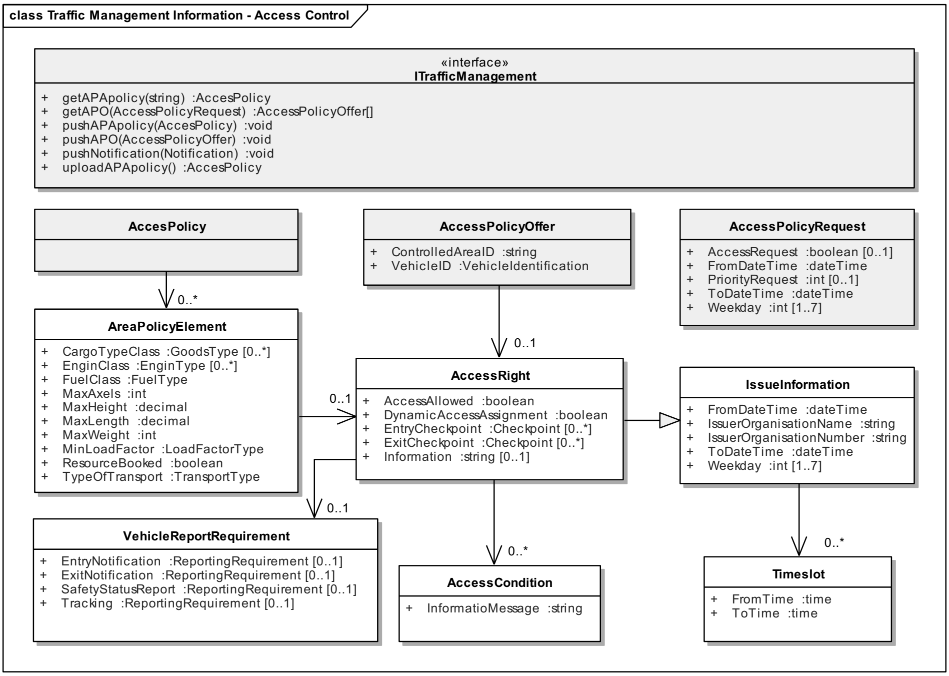

Figure 4: Information elements for the access policy

many informational properties related to their vehicle. Also, the freight management may use the access policy definitions to better plan the transport operations ahead due to their knowledge of their vehicle fleet and cargo to be carried. The traffic management APIs defined in Figure 4 can thus be used by any of the system components in Figure 3.

4.2 Local Access Control

The distributed access control mechanism can also be used for local control and monitoring of a specific Controlled Area. To show this, the mechanism was used as access control for tunnels. In this scenario a tunnel is surrounded by an approaching area, which is guarded by an RSE, for discovering approaching vehicles and communicating with their mandatory in-vehicle tunnel applications. The tunnel access policy contains information about the road network around the tunnel, approach area, holding area, by-pass roads and cargo restrictions that apply to the tunnel, which determines the final access rights of the vehicle[10]. The new element in the tunnel access control compared to the full distributed city/regional access control is the use of a dynamic parameter that gives conditional access until the vehicle actual is present at the Controlled Area (i.e. tunnel) entrance. This is

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[10] Please refer to the appendix in reference [Lyk11] for a complete example of a tunnel access policy XML file.

represented by the parameter *DynamicAccessAssignment* in Figure 4. Also, the entrance decision is given by a Tunnel Controller, and not decided by the in-vehicle tunnel application due to the dependency on the necessary tunnel status (e.g. amount of dangerous goods (DG) present, number of vehicles present, etc.).

4.2.1 Realization and Demonstration

Both the city/regional access control application and the tunnel access control application were in SMARTFREIGHT defined as mandatory applications, and download of the applications was triggered by Service Advertisement (SA) messages (a service residing in the Facility layer of the reference protocol in Figure 2) broadcasted by RSEs. When the vehicle enters a RSE coverage area, the vehicle receives a SA message containing an URL of wherefrom the access control application can be downloaded (the URL points to the HMC that manages and distributes applications - see Figure 3). The in-vehicle OBE may choose whatever transmission medium available for the actual download, which was handled by the CALM Manager service. The SA service also ensures that the access control applications are notified about the XML-based access policies.

In the SMARTFREIGHT demonstration, which was held in the city of Trondheim, Norway, a non-DG type of cargo was transported without any access restrictions. Then a reload of DG cargo[11] gave restrictions for entering the inner city area of Trondheim as this area was defined as a Controlled Area with access restrictions regarding DG in the access policy. The tunnel access policy used in the demonstrations allowed only a certain amount of DG classified cargo into the tunnel at a time. *Our* vehicle was therefore instructed to hold and wait at a waiting area before entering the tunnel. Figure 5 shows the driver display where the vehicle is asked to hold before entrance. The communication was based on IPv6 and NEMO, which ensures a fixed contact point towards the vehicle independent of physical point of attachment, while CALM enabled connectivity through 2G/3G and CALM M5 when available. For more information about the demonstration, please refer to the video in [MS10] and the demonstration handout available at the SMARTFREIGHT home page.

The SMARTFREIGHT services are generic and independent of implementation technology. However, some of the services require more from the ICT infrastructure than others. E.g., the download of mandatory applications requires some trigger mechanism like the SA service used in the demonstrations. Possible gate entry technologies to use as triggers can include the WiFi based RSE (as in SMARTFREIGHT), toll collection tags based on DSRC, and geofences based on GNSS information. Also, the introduction of distributed systems where the vehicle is integrated in the information exchange will encompass some challenges with non-supported vehicles without any OBE. Using cameras with ALPR is one alternative, while another is to integrate some level of service support in the forthcoming standardization of electronic registration books that can be integrated with in-vehicle toll collection tags.

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[11] The cargo were equipped with communication capabilities on the OGE (i.e. CEN DSRC), informing directly the vehicle's OBE about itself.

Dangerous Cargo in Tunnel
Tunnel: Elgeseter North
Delayed access - Go to holding area.

Figure 5: Access restricted areas

5 Conclusions

This paper has described how SMARTFREIGHT has relied on a distributed systems architecture, as standardized in both ETSI and ISO as the European Communication Architecture and CALM, respectively, and open services with clearly defined service interfaces for interoperable information exchange between the distributed systems to meet the increasing challenges within transportation today. The use of new emerging ICT enables the integration of individual vehicles in the traffic management for more targeted and effective traffic control and monitoring. Also, the continuously connected vehicle will thus support the freight management with real-time information for improved transport and logistics operations.

The approach has been realized and successfully demonstrated for an use case showing access control on both a wider and a local area. As far as we know, SMARTFREIGHT is the first to define a data structure that can express simple as well as advanced traffic management policies. This opens for exchange of pre-defined policies as well as dynamic policies that can be used in case of abnormal traffic situations. The same structures also allow for use both in a fully distributed case and the more local tunnel access control case. The services are developed independent of existing ICT infrastructure, but an advanced underlying heterogeneous wireless infrastructure will improve the services' functionality and capabilities.

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