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The Role of Mobile Network Operators in Intelligent Transport Systems: Situation Analysis, Challenges and Suggested Approach

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***Abstract*—In recent years, the role of Information and Communications Technology (ICT) in automotive has been accentuated, as services requiring vehicle-to-infrastructure ("V2I") networks to communicate with off-board software have been multiplying. While current legislation, policies and network infrastructure generally limit such off-board services to infotainment (for example in-vehicle hotspots for media streaming, web browsing from passenger mobile devices) for safety and security reasons, many industry analysts but also the research community predict that the automotive landscape of 2025 will be different. Next generation mobile networks are expected to provide the necessary quality of service (e.g. low latency, high throughput) to support a broad range of applications, from infotainment to mission-critical telematic applications that involve partial or full remote vehicle control. At the same time, such mission-critical applications have already started to appear as Proof-of-Concepts (PoCs), in controlled environments (for example controlled sections of highways, or test tracks). In this paper, we investigate the role of Mobile Network Operators (MNOs) in such applications. The paper starts from an overview of the current status of automotive/ICT industry from a market, policy and technology perspective. Subsequently, we present results from a study of two use cases performed within Ericsson Research. The authors use learnings from these use cases and the current industry status to form a general understanding on the challenges that MNOs will face as network infrastructure providers for automotive applications, as well as strategic options for MNOs to address these challenges.**

I. Introduction

"Intelligent Transportation Systems" (ITS), is an umbrella term referring to systems that integrate Information and Communications Technology (ICT), with vehicles and transport infrastructure to improve safety, mobility and environmental sustainability in transportation networks [1]. Such systems are expected to involve multiple actors[1] and provide services over wireless networks, ranging from vehicle occupant entertainment, to traffic flow optimisation and accident prevention. An essential element of an ITS system is wireless connectivity, applicable to both cross-vehicle communication (vehicle to vehicle or "V2V"), and vehicle to infrastructure communication ("V2I")[2]. Automotive wireless market is a new but rapidly growing industry, expected to expand by 41 percent to 1.8 billion dollars by 2018 [2]. The GSM Association (GSMA) predicts that by year 2025, every car will be connected and raises projected revenue to over 19 billion euros by that year [3]. Based on the above facts and projections, the wireless automotive market presents a key growth opportunity for Mobile Networks Operators (MNOs).

The level of involvement and role of MNOs in ITS are not yet clearly defined. One one hand, MNOs are in an advantageous position to capitalise in this rapidly growing market given an already existing network infrastructure, ownership of spectrum, and technological expertise in management of cellular networks for large numbers of subscribers. On the other hand, the nature of applications of ITS as well as regulatory and market barriers pose multi-faceted challenges that MNOs have to address.

The main questions discussed in this paper are (a) what are the challenges that MNOs face to support ITS and (b) how can these challenges be addressed.

The structure of this paper is as follows. In section 2, the authors provide overview of the current status of ITS and correlate it with the transformation of ICT industry. In section 3, we discuss the challenges for MNOs, based on information provided in the previous section, as well as a case study of two use cases. These challenges are multi-faceted, on a market, business and technological level. Section 4 presents a number of strategic options for MNOs to address the aforementioned challenges, as well as some early work done on Ericsson Research with regards to development of an ITS testbed in the suburb of Kista, Stockholm, Sweden. Finally, we conclude by highlighting key findings as well as discuss future work.

[1]Depending on the services, ITS may include vehicles with wireless connectivity, sensors, roadside infrastructure, pedestrians as well as computational resources/software in off-board systems, e.g. hosted in the cloud.

[2]Depending on their nature, ITS services may use V2V or V2I or both types of communication. The reader should note that "V2V" communication can be realised over infrastructure, or it can be direct, using short-range radio communication (see also section 3).

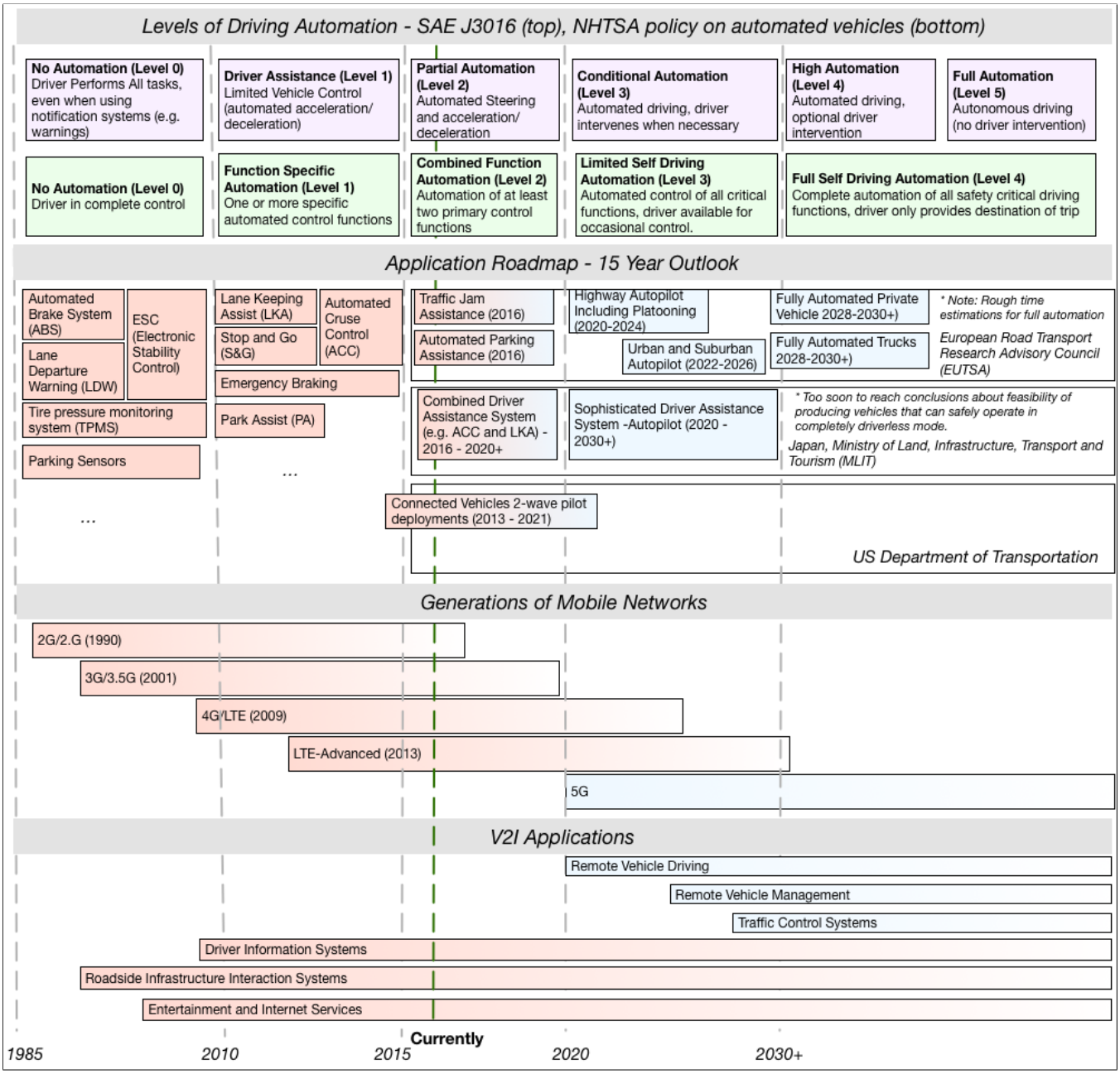


Fig. 1: This figure illustrates the roadmap for vehicle automation and the current status of the implementation in United States, Europe and Japan. The top part of the figure separates the transition towards self-driving (autonomous) vehicles in different levels, from vehicles completely controlled by human drivers (no automation) to driverless vehicles which do not involve human in-the-loop. The taxonomy presented here is based on the well-established levels of driving automation standard from the Society of Automotive Engineers (SAE) [4] as well as similar levels presented in the National Highway Traffic Safety Administration's (NHTSA) policy on automated vehicles [5]. Based on the descriptions of the automation levels, readers should note the increasingly important role of software, as the level of automation increases. The middle part of the figure shows the implementation roadmap of ITS applications for each level of automation. While many applications already exist for level 0 and level 1, level 2 ITS applications are currently being developed. In fact, roadmaps for development of applications for level 2 and above are only now being established in Europe [6], Japan [7] and United States [8]. Many of these applications, especially in Japan and US are being pilot applications in specific geographical regions. If we temporally correlate the development of ITS applications with the evolution of mobile networks, we identify clear opportunities for MNOs to support more than infotainment-type of ITS applications: as vehicles become more autonomous, they will be able to be managed remotely from off-board software. Emergence of 5G networks will provide the necessary reliability and efficiency for vehicles to communicate between them and towards software running in the cloud, thus supporting new, more "mission-critical" type of applications and unlocking new value for the MNOs. More information on these types of applications can be found in table I. Readers should note that the dating in this figure is approximate (this applies both to ITS application automation taxonomy and roadmap as well as to the evolution of mobile networks and V2I applications).

II. ITS Background Study

Connected vehicles have existed in the market for more than 20 years. Some examples include automotive navigation systems that make use of satellites for determining location (for example navigation systems supporting Global Positioning System - GPS), electronic toll collection systems (some of them using high-frequency short range communication technologies) as well as infotainment services (for example mobile broadband-based media streaming).

As technology in vehicles progresses and drive-by-wire systems replace mechanical parts, vehicle OEM manufacturers increasingly rely on software to improve efficiency and vehicle performance [9]. Recently, mobile application platform providers that have traditionally targeted mobile terminals such as mobile phones and tablets, have taken initiatives to expand their platforms to vehicles.

Prominent examples are Google and Apple with their *Android Auto* and *CarPlay* platforms respectively, that provide the same functionality through the same applications and user interface regardless of the vehicle model [10]. Indicative of the accentuated role software plays in contemporary automotive industry, is an effort from regulatory authorities worldwide to create a roadmap for fully autonomous vehicles. This gradual process involves replacements of human driver functions by software to an increasingly greater degree (see figure 1).

As vehicles become increasingly autonomous and controlled by software, they create new opportunities not only for intra-vehicle applications, but also for remote vehicle management[3].

Table I shows a categorisation for current and future ITS that require "V2x" connectivity[4]. V2x connectivity is an umbrella term, covering V2V or V2I or V2P (vehicle to pedestrian) type of communication, or any combination of the aforementioned. The categorisation is based on the network requirements of the application and is meant to illustrate the differences in network QoS services will require from mobile networks.

Even though quantification of these requirements is not explicitly standardised yet, there exist consensus among researchers that some of the future ITS services, may require sub-10 millisecond latency. These levels of latency are not possible with the current generation of mobile networks. 5G technologies are expected to provide the necessary QoS to enable categories of applications such as remote vehicle management and remote driving. Such application categories are not possible with the current generation of mobile networks.

Currently, two major families of standards are being adapted to support V2x type of communication. On one hand, IEEE 802.11p-based solutions [13] and on the other, 3GPP-supported Long-Term Evolution (LTE), with Proximity Services (ProSe) support for device-to-device (D2D) communication [14].

There are two parallel, major standardisation activities for IEEE 802.11p-based standards. European Telecommunications Standards Institute (ETSI) develops the ITS-G5 standard [15], whereas its US counterpart is known as Dedicated Short-Range Communication (DSRC). Both Europe and North America have allocated frequency bands for ITS. With regards to spectrum allocation, North America, has allocated the range between 5.85 and 5.925 GHz (75 MHz for 6 service and 1 control channel), whereas Europe the range between 5.875 and 5.925 (30MHz for traffic safety and 20 MHz for traffic efficiency).

Major advantages of 802.11p-based standards over LTE are the non-reliance to network infrastructure, as well as its fully distributed nature, which eliminates single-points of failure (e.g. base stations). On the other hand 802.11p-based standards cannot provide the quality of service that LTE provides, due to the way the LTE clients access the network without the presence of a central scheduler. Adding to the argument of Quality of Service in favour of LTE, 802.11p uses unlicensed spectrum, whereas LTE networks operate in licensed parts of spectrum. The latter excludes interference from background noise, whereas the former cannot guarantee that other third-party devices do not emit in the 5.9 GHz unlicensed band.

In tandem with 802.11p standardisation, 3GPP is working on enhancing LTE with V2x support. Release 14 dated September 2015 identified potential use cases and require-

TABLE I: A taxonomy of applications of ITS requiring V2I connectivity

Service Category	Exemplary Applications	Network QoS
Entertainment and Internet Services	Media Streaming, Web Browsing, Vehicle HotSpot, Firmware Downloading, Mobile Applications etc.	No latency, no throughput requirements (best-effort internet traffic)
Roadside Infrastructure Interaction Systems	Mobile payment systems such as toll booths and parking, intelligent traffic lights, contextual street signs, etc.	Medium latency (<150ms), medium throughput (1 Kbps)
Driver Information Systems	Navigation, oncoming traffic information, e-call	Low latency (<100 ms), medium throughput (0.5 Mbps) [11]
Remote Vehicle Management	Fleet Management (e.g. truck delivery service, bus service, garbage collection, ambulance dispatch, etc.)	High latency (<500ms), high throughput (1Mbps to scale according to number of vehicles)
Traffic Control Systems	Real-time traffic management prioritisation (e.g. yield to emergency vehicle), accident avoidance, etc.	Very low latency (<5ms), high throughput (1 Mbps to scale) [12]
Remote Vehicle Driving	Remote transportation services (e.g. taxi, bus, truck), remote emergency response services (e.g. fire brigade, police).	Very low latency (<5ms), very high throughput (3 Mbps) [12]

[3]As "vehicle management" in the context of this study we define a function which monitors and controls a group of vehicles. Examples of vehicle management functions can be truck or bus fleet management, but also traffic management in congested areas. The management functions may include interaction with nearby roadside infrastructure in addition to vehicles, for example traffic lights, signs, lights, bollards, etc.

[4]The reader should note that the quantifications of latency and throughput presented in the table are generalised estimations of values per connected vehicle, and are meant to show that different types or services have different requirements from the cellular network. Sources for establishing the generalisations for the network QoS are cited directly on the table.

ments for support of V2x services.

It is worth noting that there is already a significant amount of research supporting coexistence of both 802.11p and LTE V2x standards. Examples include use of LTE to enhance reliability of 802.11p [16], or using both LTE and 802.11p for cooperative media streaming [17]. As such, it is expected that both 802.11p and LTE technologies will contribute to 5G standardisation, as these networks can coexist and complement each other in a multi-vendor environment setup.

The next section studies two ITS applications, one level 0 (infotainment and driver notification) and one level 3 (see also figure 1). Through study of these use cases, we identify unique challenges for MNOs in ITS context, and in section 4, we discuss potential solutions.

III. Use Cases and Challenges for MNOs

A. Introduction

In the context of this paper, we studied two cases of ITS services (note that we will be using the terms ITS application and ITS service interchangeably for the rest of this paper).

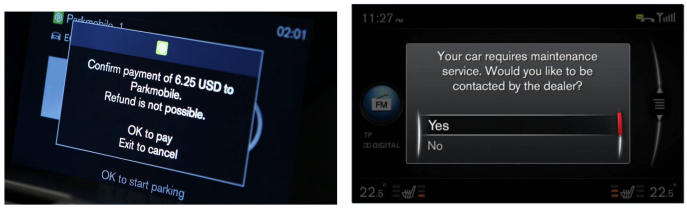
The first case is an infotainment type of service, where third party content providers can send content over an MNO network to a connected vehicle. This services are of entertainment or informational nature (level 0, as shown in figure 1). Example content providers may include music streaming services such as Spotify and parking lot vendors such as Stockholms Parkering (a manager of parking spots in the area of Stockholm).

The second case is an autonomous driving scenario in controlled environment of a mine where a remote operator sends a ”mission” to an autonomous truck. A mission in the context of this scenario, is a command to pick up minerals or dirt, move from point A to point B or deposit minerals or dirt to a collection point. The truck controls itself to reach the goal of the mission and notifies the operator only when an erroneous situation happens (for example there is a roadblock in front and the vehicle needs to continue on another way. With this solution, an operator can handle many mining trucks simultaneously and remotely.

The study of the use cases begins by an analysis of the value chain for both of the use cases, which includes the authors involved, as well as their relationships. The second part of the study, presents the business models for both use cases. Finally, from study of the value chain and the business models, we try to apply lessons learned to identify the challenges MNOs may face in ITS.

B. Driver Notification Platform (DNP)

1) Overview: The Driver Notification Platform (DNP) is a solution for telematics services, more specifically a platform for connecting automotive OEM manufacturers to service vendors. Service vendors can range from media agencies, insurance companies, to energy and utility sector. A few cases where DNP can be applied are illustrated in the figure below.



(a) (b)

Fig. 2: Example of services rendered with DNP. Micropayments for parking lots (a) and notification of workshop for booking appointment for service (b).

2) Value Chain Analysis: We can distinguish the following actors in the DNP ecosystem:

- Partners (content providers): Content providers cover a broad range of automotive industry and may verticals. Some examples of content providers are illustrated below:
  - A Bus Operator (or tethered operator) company which uses the platform to provide notifications to the bus drivers whether there are passengers waiting in the next bus stop, and their number.
  - A company building intelligent traffic lights, which uses DNP to render notification services for the status of the traffic lights (i.e. red/orange/green and for how long until it changes) to approaching vehicles.
  - An Insurance Company that gains access to the platform to enable a Pay-as-You-Drive program.
  - A Telematics Service Provider the uses the platform communication channels to deliver Tele Guard services to assist drivers in the case of a breakdown.
  - A Live Traffic Information Provider that provides real-time traffic information content to multiple Intelligent Navigation services deployed on the platform.
  - A Fleet Management Company that buys access to the platform APIs to develop its own Fleet Management Applications.
- Automotive OEM manufacturers: An automotive OEM manufacturer is a coupon that manufactures vehicles with a cellular connection, able to be connected to the DNP. As the infotainment services delivered through DNP can cover a wide range, the OEM uses these services to build and improve the customer relationship with car owners, capture aftermarket sales, collect vehicle information to improve quality control, and earn additional revenues from partners accessing or providing services through the platform. The OEM will typically integrate DNP with its existing systems, for example a heads-up display unit or similar type of interface in the vehicle, and its own cloud/backend infrastructure. Additionally, the OEM needs to integrate a Telematics Control Unit (TCU) for telematics services and a Head Unit for infotainment services in the manufactured vehicles, which are the mediators between the heads-up display unit and the radio

infrastructure of the vehicle[5].

- Service Providers: A DNP service provider is responsible for operating the DNP platform. The service provider can be a mobile network operator exclusively, or a combination of mobile network operators for connectivity and a cloud vendor for hosting the platform.
- Vehicle Owner/Driver: A vehicle owner accesses the services of DNP through the heads-up display (or similar type of interface) installed by the automotive OEM manufacturer on their vehicles. Note also that the vehicle owner/driver can be a private individual or an organization such as a bus, taxi or truck company with multiple drivers and vehicles.
- Certificate Vendor and Validator: In order to make sure that the communication is secure, DNP uses a public key authentication and encryption scheme. The certificate authority issuing the certificate can be the automotive manufacturer itself or a third party, and all vehicles willing to access a specific service, must authenticate with a pre-provisioned certificate.

Based on the above, we can construct the value chain as shown in figure 3 below:

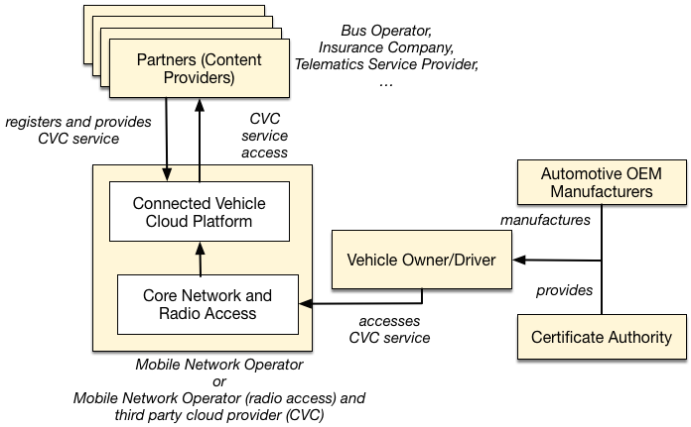


Fig. 3: Value chain for DNP, a platform for providing infotainment and telematics services to connected vehicles (preliminary design).

3) Observations: There are a few observations that can be drawn when studying the business models above.

First, if MNOs choose to be cellular connectivity providers, then they limit themselves to providing mobile broadband for connected vehicles, with tariffs being tied to a contract between the automotive OEM manufacturer and the MNO. Alternatively, if MNOs choose to host the DNP platform, they unlock the potential of being end-to-end service providers for an ever-increasing number of automotive services.

[5]Note that these units are a combination of embedded software and hardware units installed in the cars a priori, or aftermarket from a third party. This value chain analysis already assumes that these units are procured and installed by the OEM manufacturer and therefore does not consider unit vendors as part of the analysis.

The decision on which of the two cases is beneficial for MNOs to pursue, depends on the characteristics of services to be provided in the short term, for example a service to contact a repair shop or micro-payments such as the ones illustrated in figure 2 will have frequent network traffic, which may entice MNOs to stay within their traditional cellular connectivity vendor role. However in the longer term, and especially with the standardisation of 5G, MNOs may choose to become service vendors.

C. Remote Mining

1) Overview: The use case involves multiple autonomous trucks, collecting mined material from one site and depositing it to the other. An operator assigns tasks to tracks remotely and monitors their progress from a control room. In case of exceptional situations, wherein a truck cannot perform its designated mission, the operator intervenes to address the situation at hand.

2) Value Chain Analysis: The partnership involves multiple actors, namely:

- An automotive manufacturer (OEM Manufacturer), which designs and creates an autonomous vehicle. The vehicle uses cellular connectivity to obtain information on a strategy - also referred to as mission - to execute and decides by itself how to execute it. In the case of the mining scenario, the mission is to move from point A to point B, pickup or deposit mined material.
- An operator (Remote Vehicle Operator), which can be either a person or intelligent software, that designs the missions and sends them to the vehicles. The operator can be a subcontractor to the OEM manufacturer, or the OEM manufacturer itself, or another party. In the case of this particular use case, the operator software and human using it was provided from the OEM Manufacturer.
- A network access vendor (Mobile Network Operator), which provides cellular connectivity between the automotive manufacturer and the operator.

The value chain in this case is very straightforward. From preliminary discussions with OEM Manufacturer and the MNO involved in the use case, we deducted that autonomous driving still needs to be executed in a tightly closed loop for safety and security reasons, hence the fact that the number of players is rather limited with little room for expanding to more actors. This is also the reason for current use cases for autonomous driving being concentrated in controlled or semi-controlled environments such as mining sites.

In contradiction to the DNP case, the intelligence in this use case rests in the autonomous vehicles and the Remote Vehicle Operator, as there is no platform to mediate service provisioning.

D. Identification of Challenges For MNOs

An immediate conclusion we can deduct after studying the use cases is that the role of MNOs in ITS will be flexible in the short term:

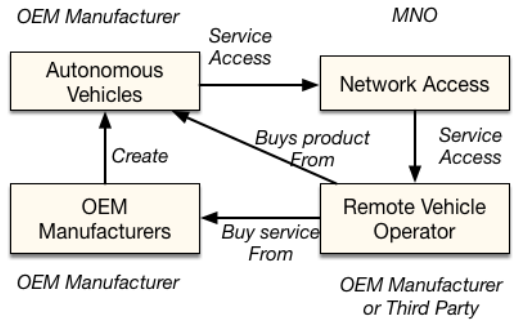


Fig. 4: Actors and their relationships in remote mining use case.

- For infotainment and telematics types of applications where the cellular network does not carry any instructions that can affect the behaviour of the vehicle itself, we can expect the emergence of and design towards platform economies. The MNOs are envisioned to be the platform provider of a multi-sided market. On the lower end of the market, the OEM automotive manufacturers with connected vehicles and on the high end of the market the content providers with a multitude of services rendered securely over the platform.
- For autonomous driving type of applications where the cellular network carries instructions affecting the behaviour of the vehicles, a more controlled environment is required for regulatory/safety/security reasons. In this environment, MNOs are seen in their traditional role as platform providers.

In the longer term, MNOs should start being more than cellular connectivity providers, as competing IT players bolstered by standards using unlicensed spectrum (such as the IEEE WAVE family of standards) will put more competition to the network transfer advantage the MNOs currently have.

After a more structured analysis of the two cases, we identify the transformation of business models. This applies both to automotive sector, as well as to MNOs. In this paper, we will focus on the transformation of the business role of the MNOs, which we study from various aspects.

- We begin with the challenge of *service differentiation and service multiplication*, as result of expansion in ITS. Currently, MNOs limit themselves to be connectivity providers for Mobile Broadband (MBB), Voice and Video services. However, to support mission-critical ITS services in 5G (see figure 1), MNOs need to provide reliable connection for this services, while at the same time they provide legacy MBB service to their subscribers. It is also likely that ITS services will have much shorter lifecycles than the decades-long lifecycle of traditional voice, messaging and MBB services. For example, in the case of the DNP case presented in section 3.B, the service lifecycle was on average 6 months. This means that MNOs can no longer afford manually operated business support systems and operation support systems (OSS/BSS)[6] and automation has to play an important role.

- Additionally, the challenge of *charging* for ITS services is one that came up repeatedly in discussing both the presented use cases. The traditional billing models of MNOs rely on use of volume of data, however, this may not apply to many use cases in ITS, who either use the mobile network to transmit and receive large amounts of data (wherein traditional charging models would make the use of service prohibitively expensive) or transmit and receive small amounts of data (in which case the service is not financially viable). An example of the latter case was present in the remote mining scenario, wherein the remote operator only used the cellular network to transmit missions (with a rough average of a few missions per hour), as well as the vehicle sending small-sized mission execution updates back to the operators. The total amount of traffic per vehicle amounted to a few kilobytes per hour. New pricing models which include paying for the use of service (e.g. per km travelled) may be something to consider.

- Finally, the issue of cross-network vendor collaboration is crucial in ITS. Examples are ITS services requiring network coverage over wide areas, for example across countries, or areas with challenging geography, e.g. across sea routes, within tunnels, etc. This may mean that the ITS service is rendered by more than one network vendors. Another concern is that of security. For example, when examining the remote mining case above, the OEM manufacturer had their own cloud software which interacted with the vehicle, and used a third-party cloud provider for rendering the remote vehicle operator service. In the DNP use case, the MNO could also provide the cloud for the services as well as the interface for these services to access the vehicle. Both configurations should be valid in the long term, as they serve different customer segments and thus different requirements. This puts extra pressure on the MNOs who now have to collaborate with a larger variety of actors in order to provide the service, and *a priori* agreements that are setup manually to a large extend as a the result of complex agreements between the vendors, and eventually negatively affect the ITS service deployment lead-time.

IV. Addressing Challenges of MNO role in ITS through automation

MNOs are in an advantageous position to play an important role in ITS, given their current assets such as wide-area network coverage through already setup network infrastructure, spectrum ownership as well as technical knowledge in managing mobile networks. However, due to the disruptive nature of the future ITS market, which will be a culmination of converged ICT and automotive industries, MNOs have to transform their business model. We believe that this transformation will ultimately require automation in the

[6]In the telecom domain, a business support system (BSS) consists of all the customer-facing functions, (for example sales and support), whereas an operations support system (OSS) consists of all the functions and processes internal to an operator (for example management of telecom infrastructure such as maintenance, upgrading, etc.)

MNO's OSS/BSS, and replacement of human functions with automated, machine-driven processes.

First, in order to address the challenge of service differentiation and service multiplication, the MNOs will need to develop a much more flexible, automated OSS. We have already developed concepts around process automation within OSS in previous work [18], wherein we described the concept of "network slicing" as automated allocation of network resources in an MNO network from a shared pool of resources. We are planning developing this concept as well as prototypes around this, as this is also core part of the 5G standardisation effort.

Second, in order to answer cross-network vendor collaboration, we are developing concepts of ad-hoc MNO partnership with other network vendors, in order to create a service. This ad-hoc partnership includes automated negotiation between vendors of capabilities (in terms of network resource availability) and charging, for a specific service.

V. Conclusion

In this paper, we have presented an overview of ITS and pondered on the future role of MNOs in this ecosystem. We started with an overview of the current status of ITS ecosystem and linked the transformation of the automotive industry to the transformation of the ICT industry, and discussed how MNOs are in a unique position to take advantage of the new, converged ICT and automotive industry. Through the study of two use cases, we identified a set of challenges that in our view are crucial for MNOs to succeed in this goal. We concluded by discussing current research the authors are doing towards addressing these challenges, focusing on automation of MNO's OSS and BSS for cost-effective support of the dynamic ITS ecosystem.

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