mAutomotive

Connecting Cars: The Technology Roadmap




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Executive summary

Drivers and their passengers are increasingly seeking in-vehicle mobile connectivity to make travelling by car a safer, faster and richer experience. To meet this demand, mobile operators and automakers need to collaborate. In particular, mobile operators need to enable remote management of the SIM card and deploy network technologies that support widespread, high-bandwidth connectivity. The mobile industry is developing an embedded SIM, which can be remotely provisioned, or swapped out, without any need to have physical access to the mobile device. The standardisation of the remote management of SIMs is scheduled be completed in 2012.

Mobile networks are also evolving rapidly as operators deploy new broadband technologies, such as HSPA+ (High Speed Packet Access plus) and LTE (Long-Term Evolution). But is quite difficult to predict how LTE, in particular, will be deployed regionally given that:

- Network evolution is based upon the commercial decisions of individual mobile operators, based upon the needs of their cumulative customer base;
- LTE requires additional spectrum to be deployed, which will partly need to be re-farmed from current mobile networks;
- Spectrum licensing is regulated at a national level.

The rapid evolution of mobile networks is in contrast with the product development cycles in the automotive industry, where it generally takes three to five years to develop new vehicles, which then have a typical lifespan of between seven and ten years. The long lifecycles of vehicles mean it is necessary to:

- Create durable connectivity solutions, which require few hardware updates and support over-the-air updates for systems and services.
- Create interoperable solutions, which can move across brands and models, as well as provide economies of scale wherever possible (even across automakers).
- Manage connectivity in a flexible manner that can accommodate potential changes in user services during the long lifecycle of the vehicle. Automakers are seeking connectivity solutions that can adapt to a wide range of use cases, such as a change of business model, a change of mobile operator and a change in the ownership of the vehicle.

As they seek to meet these requirements, automakers have several options to connect a vehicle: Embedded devices, Tethered solutions, Integrated (using handsets)[1]. These three connectivity solutions are not mutually exclusive. A tandem approach is frequently used to separate the allocation of costs to the beneficiary (i.e. the automaker or the driver) or to provide an option for technology upgrades where necessary for newer-generation or higher bandwidth services. This portfolio of solutions is likely to continue to co-exist in the future.

Embedded solutions need to be able to access networks with the bandwidth and coverage characteristics necessary to support the envisioned services, while also being “future-proof” to handle network evolutions. There is a risk, for example, that 2G networks in some regions may be switched off within the lifecycle of vehicles currently under development. While module costs will continue to fall, the rate of decline in the cost of LTE automotive-grade modules, in particular, will depend upon how fast the technology gains economies of scale.

For embedded solutions, many automakers are looking to bring down the cost of data connectivity (both domestic and roaming) to a level where services with a moderate data requirement, such as remote diagnostics, traffic information and connected navigation, can be provided through an embedded SIM with a single upfront payment for the lifetime of the car.

Further areas for potential cross-industry cooperation include:

- Advancing enablers, such as remote provisioning, billing, roaming, security;
- Operational improvements (such as improved service delivery by different connectivity methods (tethering and smart phone integration), eCall deployment, defining common requirements for telematics services and optimising data usage);
- Exploring the opportunities for new business developments, including joint application programming interfaces (APIs) and how to create and foster a scalable, viable and user-friendly application ecosystem.

1 **Embedded**: Both the connectivity and intelligence is built directly into the vehicle.
Tethered: Connectivity is provided through external modems, while the intelligence remains embedded in the vehicle;
Integrated: Connectivity is based upon integration between the vehicle and the owner’s handset, in which all connectivity and intelligence remain on the phone.

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1. Introduction

This whitepaper analyses the complex dynamics facing the mobile industry and automakers in the development and deployment of telematics and infotainment systems for passenger vehicles.

It outlines key industry characteristics, available resources for service deployment and the requirements for these services, both with regards to the current context as well as looking into the future. The paper also explores the existing barriers and opportunities relating to the wider deployment of telematics and infotainment services, through improved cooperation between automakers and mobile network operators (MNOs).

The scope for this whitepaper has come from the GSMA Connected Car Forum activities where global operators and automakers have met from June 2011-December 2011 to cooperate over these challenging topics. Companies include:

- Operators: AT&T, Bell Canada, China Unicom, KPN, KT, NTT Docomo, Orange, Telecom Italia, Telefonica, Telenor, Telstra, Vodafone;
- Automakers: Audi, BMW, Ford, GM, Honda, Hyundai, Jaguar Land Rover, Mazda, Nissan, Peugeot, Renault, Subaru, Toyota, Volvo, VW.

This whitepaper is aimed at:

- product planning executives, telematics, innovation and technical experts from automakers;
- business development executives, embedded mobile specialists, and technical experts from mobile operators.

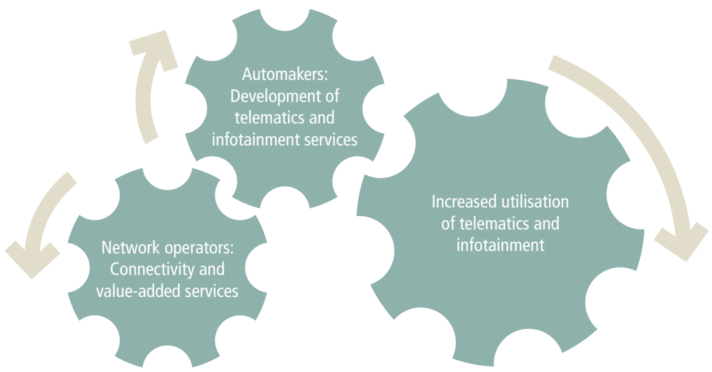
The document is also valuable for other value-chain actors, which often play intermediary roles between the mobile operators and automakers in the development of these services. Finally, the white paper is relevant to policy and regulatory personnel wishing to understand the challenges facing these two different industries in the deployment of connected car services.

The document has three primary elements:

- Cellular network technology: the fundamental functionality of cellular networks, the current deployment status of technologies and the outlook for network evolution;
- Connectivity in the automotive industry: an overview of the automotive industry's approach to connected services, the technological requirements for these services, and the outlook for service development:
- Identification of areas for cross-industry cooperation between mobile operators and automakers that would support the deployment of telematics and infotainment.

This paper's underlying premise is that only through cross-industry collaboration between automakers and mobile operators will it be possible to remove current barriers and unlock obstacles for the safe delivery of connected services and applications in cars, as increasingly requested by drivers.

Figure 1. Automaker and Operator Interaction to Foster Telematics and Infotainment Services



Source: GSMA 2012

1.1 Development challenges for cross-industry connected services

The following graphic describes the cooperation challenges between automakers and mobile operators:

Figure 2. Problem Statements between Automakers and Mobile Operators

Historic cooperation difficulties across operators and automakers

- First telematics services often resulted in misunderstandings between Operators and Automakers
- Regulatory changes have stagnated development in recent years (EU)

Market structure

- Market dominated by relatively few automakers wanting global solutions
- Fragmented market of services and devices
- After-market expected to grow significantly in near future
- Closed ecosystem

Service delivery challenges

- Ubiquitous coverage is required for most telematics services viability
- Services are often not seamless, given fragmented connectivity approaches
- Driver distraction concerns impose specific, unique obligations on services for deployment
- Current business models have few proven track-records for directly covering costs of services
- Security & privacy issues are given increased importance as deployment of connected cars increases with increased attention of hackers
- Fear of roaming costs have reduced the utilisation of telematics services (switched off to avoid risks in border areas)

Market evolution

- Evolving market demands, as more data intensive services are expected to be deployed on massive scales requiring new technologies, business models and cooperation
- Operator assets will need to meet these evolutions in order to maximise opportunities and become active players in the value chain (beyond connectivity)
- Automakers will need to build services compatible with the different evolving cellular network

Source: GSMA 2012

Addressing the problem statements outlined above requires a meeting point between:

- mobile network technology and operator services;
- the requirements of the automotive industry;
- the final consumer.

Arriving at this meeting point will require both industries to respond to the basic differences in the industrial structures, to overcome the existing service delivery challenges, and finally to meet the ever-changing market demands.

2. Cellular Networks' Capabilities

This chapter reviews the basic characteristics of mobile network technologies, some of the key factors affecting their future deployment, their current deployment status and expected evolutions. This chapter seeks to provide general technical information on key issues facing the mobile industry, as a starting point for the further development of connected car services.

In existence for more than 25 years, the mobile telecommunications industry evolved to deliver a service to customers, which was equivalent to that of the fixed line telecoms industry's telephony service, but without the inherent restrictions on movement that wires imply. In order to meet this top level service requirement, two basic principles drove the design of the mobile telecoms network architecture and technology that remain the bedrock upon which all mobile telecoms services are built upon today:

- A network should be highly available. The 'wired' part of a cellular network is designed to incorporate a degree of redundancy and resilience, so that in a situation where either equipment or connectivity between network elements fails, the end user experience is unaffected.
- The customer should be certain that their calls (and now their data traffic) are secure and will be routed correctly.

These principles mean that a number of the key service factors that are implicit in fixed line telecoms services had to be explicitly replicated for mobile technology. For example, the uniqueness of the end user requires authentication and authorisation services for mobile customers that would not have been needed with a wire, since the wire itself ensured the uniqueness of the end point.

Whilst these basic principles are fundamental to all that has followed in the mobile industry today, they can also offer great value to the application of mobile telecoms technology to other industries.

2.1The principles underpinning mobile networks

The fundamental principles, which underpin how mobile networks are implemented today, include:

- **Redundancy, Resilience and Availability:** the network should be functioning 99.999% of the time.
- **Authentication and Security:** the network and a subscriber's device establish a "trust relationship", through encryption algorithms and network-generated "challenges" to devices, to assure the network that the subscription is entitled to service. These principles are implemented through what is popularly known as the SIM Card, but which is technically referred to as the Universal Integrated Circuit Card (UICC) card, and through the authentication centre (AuC). Furthermore, a number of mechanisms help to ensure that the traffic on the network is secure from hacking and protect the radio channel. The most vulnerable aspect, however, is the third party services or applications being run on a device connected to the network (given the uncertainty of the service source and necessity to assure that it is safe for the device and network).
- **Billing:** billing systems, working closely with the authentication and security mechanisms of the operator, are designed to identify specific events for which charges are levied against the customer's account – these are referred to as 'billable events'.
- **Subscription and Device Management:** operators are responsible for the correct management of their customer subscriptions, so that the customer receives all services that they are entitled to and equally do not receive (and as a result, is not charged) for services to which they have not subscribed.
- **Customer Care and Customer Support:** operators traditionally offer customer support via call centres, but are increasingly deploying online support as a cheaper, more efficient option for both their services and their customers' devices.

The characteristics of cellular network technology

In this section, each generation of mobile technology is considered, and characterised, based on a number of criteria – coverage, bandwidth, latency and the spectrum availability – as well as presenting other technologies that are within that same ‘generation’. These network criteria are important for the following reasons:

- **Coverage**: services that require permanent connectivity imply a need for near ubiquitous coverage. However, widespread coverage only comes with time and maturity of the technology, so whilst some of the older (but lower bandwidth) technologies available have very high coverage, the newer technologies (that deliver broadband data rates) do not.
- **Bandwidth**: services will need a certain amount of bandwidth to work successfully and to meet customer expectations. Older technologies tend to deliver lower bandwidths, whereas newer technologies deliver higher bandwidths, as they tend to utilise newer techniques of modulation and additional features, such as Multi-carrier Bonding and Multi-Input Multi-Output (MIMO) radio techniques.
- **Latency**: this is a measure of the length of time it takes for traffic to traverse the network. This is a critical factor for ‘real-time’ services, in particular, such as voice and video telephony, where a delay of greater than 250ms can have a significant impact on the consumer’s perception of the quality of the service they are experiencing.

Later in the paper, different use cases, based on these ratings, are mapped on to different generations of radio technology. This mapping serves to identify suitability, as well as to highlight gaps between requirements and what is achievable with current deployments, and hence where further investment is needed and by whom.

Why is spectrum so important?

The availability and licensing of spectrum is important in two respects. Firstly, if there is no spectrum available for the mobile technology to be deployed in, then the technology cannot be brought to market within any given market. Secondly, the spectrum band in which a technology is used affects coverage and the cost to deploy. If the spectrum allocated for a technology is at a low frequency, then larger cells can be deployed, particularly in rural areas, resulting in higher coverage levels.

- Spectrum for GSM/GPRS has been identified and licensed around the world, with a fairly high degree of alignment in the spectrum bands used.
- 3G spectrum bands have been licensed for some time in many developed markets, but some markets still do not have any 3G-licensed spectrum today.
- The latest mobile technology, Long-Term Evolution (LTE), cannot exist in the same spectrum bands as pre-existing technologies, which implies that new spectrum licenses are generally needed to deploy LTE[2]. Two spectrum bands are being widely used for LTE – the ‘digital dividend’ bands at 700MHz or 800MHz (dependent upon the market) and 2.6GHz.

The alignment of spectrum bands across many countries:

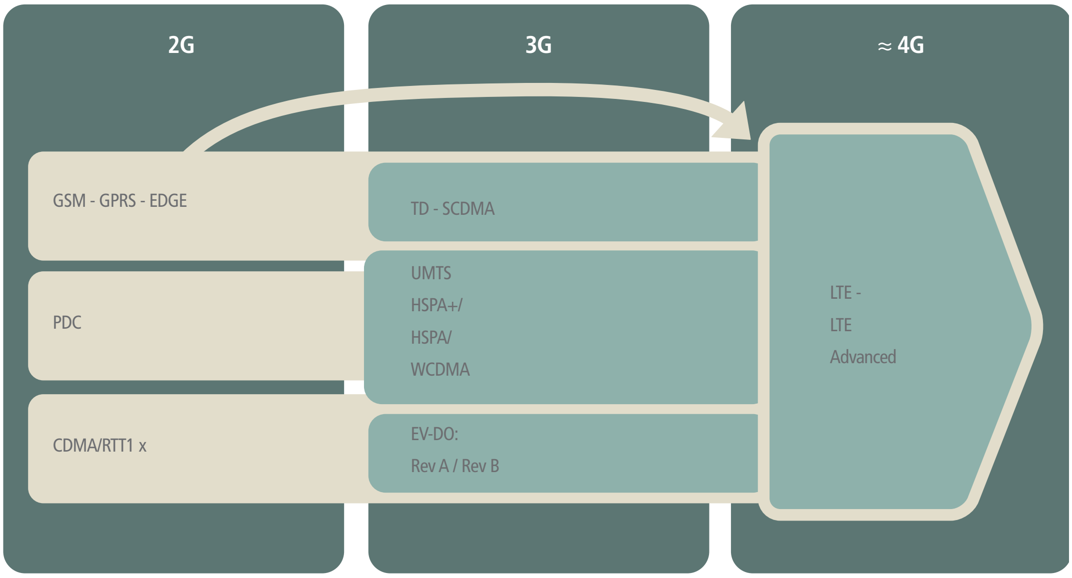
- enables radio component suppliers to realise economies of scale,
- lowers the cost of embedding connectivity for global devices (due to the possibility to use fewer radios), and
- facilitates national and international roaming between operators (given common radio technology).

What are the differences between cellular network technologies?

In mobile telecoms, much is made of the generation of technology that is being implemented by networks and supported on devices.

2 If two licenses are used, it is possible to host 3G and LTE together (ex. as NTT DOCOMO does in the 2.1GHz band).

Figure 3. Cellular Network Technology Categories



Source: GSMA 2012

- 2G has broad global operator support and wide coverage today within individual markets.
- 3G was the technology that brought the Internet to mobile. It was not until UMTS (Universal Mobile Telecommunications System) networks were upgraded with High Speed Radio Access (HSPA) technology that the mobile Internet really began to gain any true momentum. 3G and HSPA have been deployed in a large number of countries, but do not have the in-country coverage that 2G does.
- In the past 18 months, so-called '4G' technology – LTE – has been launched. This is not strictly a fourth generation technology, but is being branded as such by some operators. However, currently only a relatively small number of operators have a live LTE service; and, the coverage that these operators provide is limited primarily to cities, although exceptions do exist.

Figure 4. Summary of Today's Network Generational Characteristics on Evolved GSM core networks

Cellular Network Generation		Bandwidth Data Rate (downlink)	Latency	Current Coverage (1 Low - 5 High)
2G	GSM	9.6kbps	150-200ms	●●●●●
	GPRS	40kbps	>500ms	●●●●●
	EDGE	236.8kbps	150-200ms	●●●
3G	UMTS	384kbps	200-250ms	●●●●
	HSPA	14.4Mbps	50-100ms	●●●●
	HSPA+	42Mbps	20-25ms	●●
LTE		170Mbps	5-10ms	●

Source: GSMA 2012

2.2 The current geographic deployment status of cellular technology

Unsurprisingly, the deployments of each generation of network technology differ across regions. However, 2G technology generally offers the widest coverage except in:

- Japan and South Korea, which are in the process of finalising 2G switch-off (as part of regulatory mandates).
- North America, where some North American operators do not use GSM as their 2G technology.

HSPA+, an upgrade to HSPA, is still not pervasive in all regions.

Implementation of LTE has only begun recently and therefore does not offer widespread coverage.

Figure 5. Summary of Current Regional Network Deployment (Scale: • Low; ••••• High)[3]

Regional Coverage	2G					3G						LTE
	PDC	CDMA/ RTT1X	GSM	GPRS	EDGE	TD-SCDMA	UMTS	HSPA	HSPA+	CDMA-2000	EV-DO	
Asia/Pacific:												
Japan	•	••	—	—	—	—	•••••	•••••	••••	•••	•••	••
Korea	—	••	•	•	•	—	•••••	•••••	••••	•••	••	••
China	—	••	••••	••••	••••	•••	•••	•••	•••	•••	•••	—
Australia/ New Zealand	—	••	•••••	•••••	•••••	—	•••••	•••••	•••••	••	—	•
Rest of Asia/ Pacific	—	•	•••••	•••••	•••	—	••••	•••	••	•	•	•
Europe	—	—	•••••	•••••	••••	—	••••	••••	•••	—	—	•
Latin America	—	•	•••••	•••••	••••	—	••••	••••	••	•	•	—
Middle East and North Africa	—	•	•••••	•••••	••••	—	••••	••••	••	•	•	•
North America	—	••••	••••	••••	•••	—	••••	••••	•••	•••	•••	••
Sub-Saharan Africa	—	•	••••	••••	••••	—	•••	•••	••	•	•	—

Source: GSMA 2012

2.3 What Does The Future Hold?

How mobile networks are evolving

In its 25-year history, the mobile telecom industry has rarely stayed still for long. The original GSM service evolved to deliver data with GPRS, and then higher data rates through EDGE. Similarly UMTS was enhanced to offer HSPA, and then HSPA+, and now that LTE networks are being deployed, talk is already turning to the true 4G technology of LTE-Advanced.

LTE-Advanced will offer downlink bandwidths of up to 1 Gigabit per second and uplink speeds of up to 300 Mbps. These speeds can be achieved using high-order MIMO technology and the concatenation of multiple radio bearers. This has significant implications on the amount of spectrum required to deliver these speeds, with the need to either identify new spectrum for this purpose or to re-farm existing bands.

The same technical enhancements are also applicable to HSPA, with the potential to take HSPA+ rates to around 600 Mbps, but again a large quantity of spectrum will be needed to achieve this objective.

This does present other industries with something of a quandary: at what level of mobile technology should they engage?

3 ••••• High refers to greater than 90% population coverage and/or greater than 80% land mass coverage.

However, one characteristic of most mobile technologies is backwards compatibility. This means that, as long as you stay within the same generation of technology, you are compatible with the network, even if the network moves forwards. For example, a UMTS device will work on an HSPA+ network and an LTE device will work on an LTE-Advanced network.

Network evolution is difficult to predict

It is quite difficult to predict how LTE will be deployed regionally given that:

- Network evolution is based upon the commercial decisions of individual mobile operators, based upon the needs of their cumulative customer base;
- Spectrum licensing is regulated at a national level (generally for fixed periods, 3G licensing, for example, has an average of 10-15 years);
- LTE requires additional spectrum to be deployed, which will partly need to be re-farmed from either current 2G or 3G networks.

What could 2020 hold for network evolution in terms of regional coverage?

With this complexity in mind, the following table provides a picture of potential regional coverage in 2020:

Figure 6. Potential Regional Network Evolution 2020 (Scale: • Low; • • • • • High)

Regional Coverage	2G					3G						LTE
	PDC	CDMA/ RTT1X	GSM	GPRS	EDGE	TD-SCDMA	UMTS	HSPA	HSPA+	CDMA-2000	EV-DO	
Asia/Pacific:												
Japan							••••	••••	••••	•••	•••	•••••
Korea							••••	••••	••••	•••	•••	•••••
China			•••	•••	••	••••	••••	••••	••••	••••	••••	••••
Australia/ New Zealand			•••	•••	••		•••••	•••••	•••••	••	••	••••
Rest of Asia/ Pacific			••••	••••	••		••••	••••	••••	•	•	••••
Europe			•••	•••	••		••••	••••	••••			••••
Latin America			•••	•••	•••		••••	••••	••••			•••
Middle East and North Africa			•••	•••	••		••••	••••	••••			••••
North America		••	••	••	••		••••	••••	••••	•••	•••	••••
Sub-Saharan Africa			•••	•••	•••		••••	••••	••••			•••

Source: GSMA 2012

2G network technology:

In developed markets, operators are no longer expanding their 2G-network coverage. The spectrum dedicated to 2G is set to begin to be either phased out or be re-farmed. The speed of these changes and the nature of these changes will depend upon:

- The existing installed base of devices (including machine-to-machine, or M2M, connections that are 2G) and their associated contracts;
- The necessity to provide roaming options for 2G devices.

One possible scenario could be that very high coverage of 2G is maintained regionally, but by fewer 2G operators/bearers.

3G network technology:

The technical innovations that are being developed for LTE-Advanced are also driving increases in HSPA+ data rates. Mobile operators are faced with a decision as whether to upgrade their networks to HSPA+ or move directly to LTE.

LTE and LTE Advanced Network Technology

Continued demand for bandwidth will drive all regions towards LTE (and LTE-Advanced), but LTE is not likely to offer near universal coverage in most markets for some time. GSMA's research arm, Wireless Intelligence, portrays LTE status and development in the following manner:

- **2009-2011**: 40 live LTE networks have been deployed across 24 countries, covering 5% of the world's population
- **2012-2014**: 140 additional LTE networks will be launched globally
- **2015**: more than 200 live LTE networks across more than 70 countries

Nonetheless, the in-country LTE coverage required for the continuous availability of automotive services along road networks will require significant time.

The LTE networks being deployed today do not have a standardised technology for the support of voice services included within them. GSMA has defined a solution based on IP Multimedia Subsystem (IMS) technology through its Voice over LTE (VoLTE) project, but this has yet to be deployed in any live LTE networks; it is set to be introduced from late 2012 in many markets. In the meantime, dedicated voice services are offered on 2G and 3G networks, meaning these technologies may remain in place for some years to come. In markets where 2G switch-off is close (Japan and Korea), voice will be supported solely on 3G circuit switched equipment.

With each step along the LTE roadmap, and the addition of technologies, such as MIMO, multi-carrier bonding and self-optimising networks, the equivalent steps are being applied to HSPA as well.

What does the SIM offer?

The SIM card has been at the heart of the mobile industry for more than 20 years, helping to make the GSM family of technologies the most secure, ubiquitous and successful communications system in the world. The SIM card will remain at the heart of the system for the foreseeable future.

The SIM card is secure and it is the custodian of the subscriber's identity. It ensures that trust is maintained between the customer and the mobile telecommunications network.

The SIM card technology is evolving to meet the demands of future mobile services and applications. This evolution includes features to enable new use cases, in which mobile connectivity is embedded into a wide range of devices, machines and vehicles.

Evolution of SIM Form Factor

The form factor of the SIM card is evolving to support new business requirements. The removable SIM card form factors commonly in use today[4] will be augmented with new, complementary and standardised form factors. These include:

- smaller, pluggable form factors to allow more flexibility in mobile device form factors, and
- next generation embedded (or 'surface mount') form factors[5] that can be soldered into mobile devices and be remotely managed by the network operator.

However, the standardised 'remote management ' technologies available today do not facilitate the remote provisioning or switching of operator credentials on the SIM card.

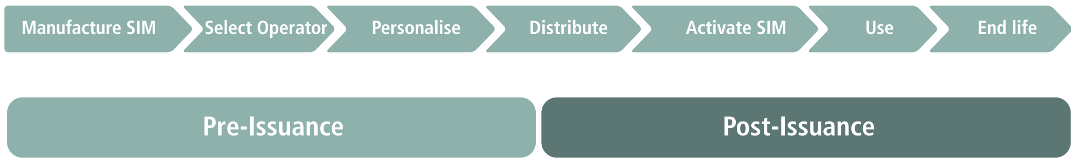
4 Defined in ETSI 102 221
5 Defined in ETSI TS 102 671

These new form factors will complement existing SIM card form factors, rather than replacing them; traditional SIM-supported devices will continue to work on operator networks. The new SIM form factors will be based on already-standardised SIM form factors and will remain as a 'physical entity', based upon operators' belief in the enhanced security that a physical implementation provides. As such, these new SIM form factors will continue to provide the essential trust and security relationships necessary to protect the data provided by all parties in the value chain.

Remote management of the SIM

Today's current generation of SIM cards are generally managed as physical entities: they are physically shipped from the operator to the customer, they are manually plugged into mobile devices and they are manually swapped and updated.

Figure 7: The Linear SIM Life Cycle Model of Today



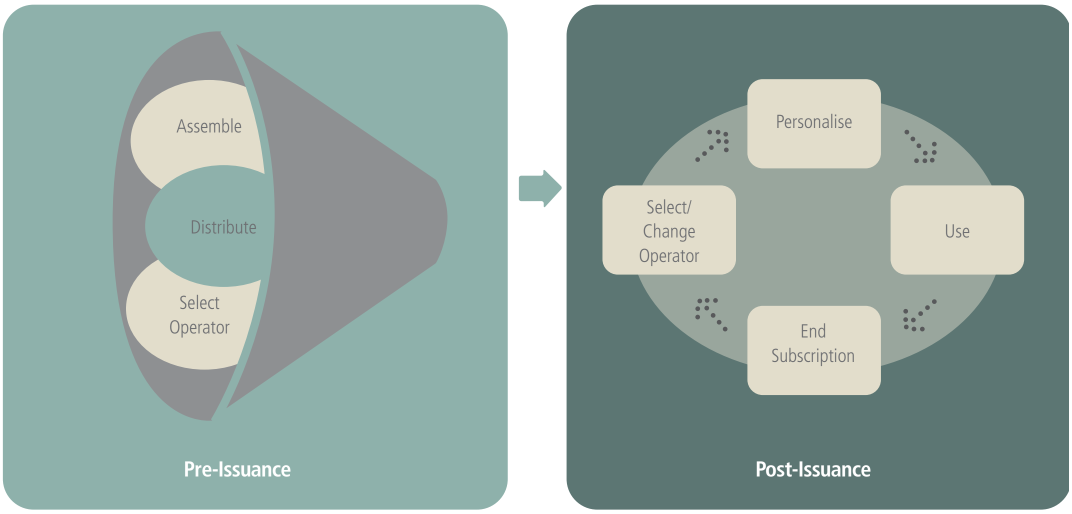
Source: GSMA 2012

The use of current generation SIM cards has, thus far, provided many benefits to the customer, including great flexibility. However the current mechanisms used to supply and manage SIM cards will need to evolve to open up new markets, in particular for services in which mobile connectivity is embedded in a wide range of devices (a concept known as "embedded mobile"). New SIM-management mechanisms will help drive global momentum for new, innovative and cost-effective connected devices that will enhance everyday lives.

To this end, the GSMA, along with a group of leading mobile operators, is driving the development and standardisation of a next generation of SIM card technologies to facilitate the remote management of the operator credentials within the SIM. The goal of this initiative is to enable remote SIM management, while retaining the security and flexibility of current SIM card form factors.

Remote management will enable operators to securely deliver, update or swap SIM credentials 'over the air' in devices equipped with the next generation of embedded SIMs. It will enable SIM cards to be remotely provisioned, or swapped out, without any need to have physical access to the mobile device. This means that next generation SIMs in embedded devices (which by design cannot be removed) can be securely updated with operator credentials right up to and, even, after the point of sale. This approach will also allow the secure re-provisioning of alternative operators during a device's lifespan.

Figure 8. Outcome-Based SIM Life Cycle Model with Repeat Provisioning



Source: GSMA 2012

SIM Provisioning Use Cases

Five primary use cases for the remote-provisioning of next generation SIMs have been defined:

Figure 9. SIM Provisioning Use Cases

Provision of multiple M2M subscriptions	An M2M Service Provider sets-up subscriptions for a number of connected M2M devices to start telecommunication services with an Operator
Provision of first subscription with a new connected device	A subscriber purchases a new type of connected device from a device vendor/distribution channel
Subscription change	A subscriber changes the subscription for a device to stop services with the current Operator and start services with a new Operator
Stop subscription	A subscriber sells his device and stops the subscription for services from the current Operator
Transfer subscription	A subscriber transfers subscription between devices.

Source: GSMA 2012

These SIM provisioning use cases are applicable to the automotive sector. Two sample automotive scenarios are described in the following text:

Sample scenario A: The operator's contractual relationship is with the vehicle manufacturer

- The vehicle manufacturer manages embedded mobile connectivity
- Pre-sale – The vehicle manufacturer ensures a valid provisioning profile is present within the embedded SIM.

  Pre-sale – The vehicle manufacturer supplies embedded SIM identity and over-the-air credentials to their subscription manager partners directly or via SIM vendor (see the next section for additional details)
- Post sale – The vehicle manufacturer provides the embedded SIM and subscription manager identities to chosen mobile operator
  - For vehicle testing
  - For live service
- The mobile operator remotely provisions the embedded SIM and provides service
- The embedded SIM ecosystem enables the vehicle manufacturer to bulk-switch serving mobile operators for vehicles post-sale.

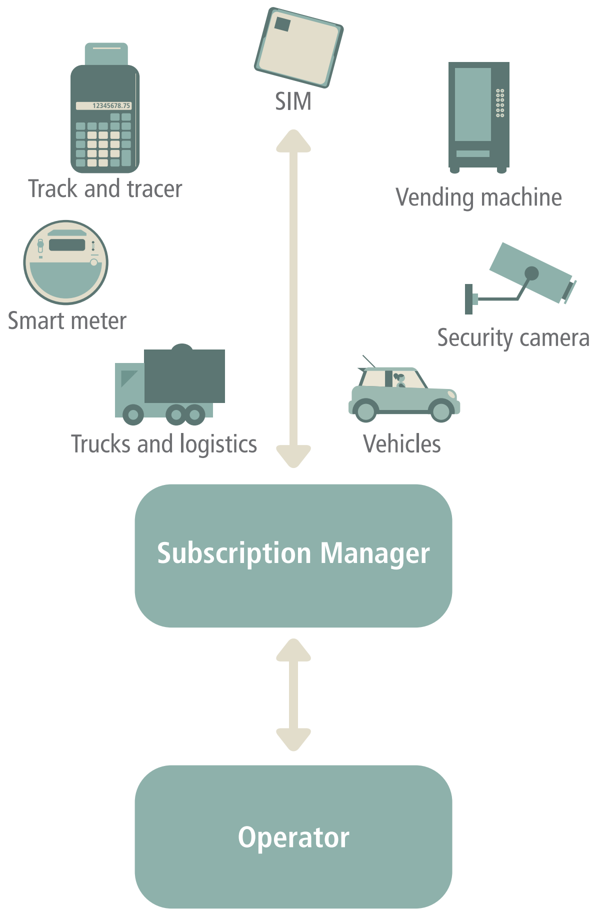
Sample scenario B: The operator's contractual relationship is with the consumer

- The vehicle owner is responsible for ensuring mobile connectivity for desired embedded mobile services
- Pre-sale – The vehicle manufacturer ensures a valid provisioning profile is present within the embedded SIM.
- At point of sale, the vehicle owner receives a SIM and the subscription manager identities from the dealer.
  - The owner provides their chosen mobile operator with the SIM and subscription manager identities;
  - The mobile operator remotely provisions the embedded SIM and provides service;
  - The dealer may facilitate this process.
- The vehicle owner may change the serving mobile operator or cancel connectivity during the lifetime of the vehicle (subject to contract)
- The vehicle may be re-sold and the new owner may obtain service with another mobile operator.

SIM Architecture and Roles

The architecture for the remotely provisioned SIM is presented in the following diagram, with the inclusion of the new role of the subscription manager:

Figure 10. Remote Provisioned SIM: Elements



Source: GSMA 2012

GSMA is still finalising the specifications of the subscription manager (as of January 2012); the definition of the SIM manager includes:

- To generate SIM profiles in real-time.
- To manage and execute mobile operator policy.
- To secure routing of profiles to the embedded SIM.

Figure 11. Remote Provisioned SIM: Roles

Embedded SIM	■ Functionally identical to a traditional SIM card ■ Next generation embedded at manufacture may have a 'provisioning profile' assigned with secret keys that allows the associated subscription manager to manage 'operational profiles' on the eUICC ■ To be standardised by ETSI Technical Committee Smart Card Project and considered in 3GPP standards ■ The technical standard can accommodate both an initial declaration of the Operator in the eUICC as well as the selection of a new Operator later. The implementation will depend upon the commercial agreement between the operators and their customers
Subscription Manager	Manages the embedded SIM by: ■ Generating SIM profiles in real-time ■ Managing and executing of Operator policy ■ Securing routing of profiles to embedded SIM
Operator	■ Uses subscription manager to manage profiles ■ Facilitates maximum re-use of existing provisioning interfaces and processes

Source: GSMA 2012

Benefits of remotely-provisioned SIM management

The benefits of a standardised mechanism for remote SIM management include:

- Allows delivery of the operator SIM to occur independently of the embedded mobile device's distribution channel.
- Enables the management of the SIM during the embedded mobile's product life cycle, which for some M2M products could be 10-15 years.
- Protects network operator security and customer privacy.
- Re-uses as much as possible from current implementations.
- Provides scale that enables cost minimisation.

The technical standard contains sufficient flexibility to facilitate numerous business models; and, as such, the technical standard cannot provide a clear indication as to what business models will appear within the market. It is envisaged that the business models will be created through discussions between network operators and their customers.

Status

GSMA, along with a group of leading mobile operators, has already finalised the market requirements for the development of standardised embedded SIMs and for the remote management of SIMs. This has paved the way for the delivery of a worldwide-embedded SIM standard, reducing fragmentation and driving scale for 'connected' devices across various industries, including automotive, consumer electronics, healthcare and utilities.

Standardisation, already underway, is expected to be completed in 2012.

GSMA, and its partners, plan to show advanced 'proof of concepts' during 2012, with the first commercial deployments likely to follow in the near future.

What should operators consider in future co-operations with automakers?

As discussed, mobile operators are rapidly evolving their networks and services to support the demands of increased connectivity in all spheres of life. Extending the role of embedded connectivity in the automotive sector is a high priority for mobile operators.

To realise this opportunity, operators need to enable the remote management of the SIM and deploy network technologies that support widespread, high bandwidth connectivity.

Mobile operators are also seeking to better understand the automotive industry's requirements, in particular:

- How services, and their connectivity requirements, are evolving;
- How to enable all useful connectivity options for services.

Greater understanding of these two aspects will facilitate the development of tailored approaches and services to support telematics and infotainment, which better meet the underlying needs of automakers. Moreover, cross-industry collaboration will be required to overcome some existing ecosystem barriers. Operators are particularly interested in fostering this joint collaboration in areas such as:

- Operational improvements, such as how to optimise data usage, common requirements for services and improving service delivery for different connectivity options;
- New means to foster telematics and infotainment business development, such as through joint application programming interfaces (APIs), apps development and location-based services.

The Connected Car Forum enables such discussions to take place, where automakers and mobile operators can identify and collaborate on joint priorities.

3. Automakers' Connectivity Requirements

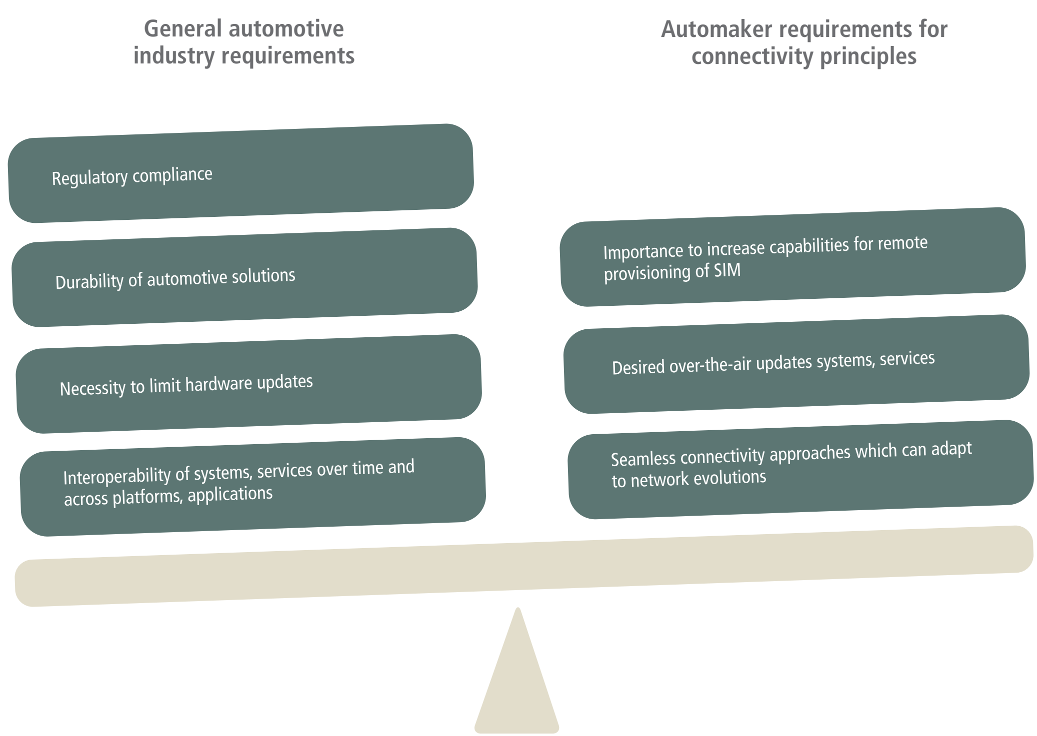
This chapter highlights automaker requirements for the development of connected car services including:

- General industry context and subsequent requirements, which impact the deployment of services;
- Approach to business models;
- Embedded modules characteristics and cost forecasts;
- Different connectivity methods for providing services;
- Performance factors for cellular technology for the delivery of specific services.

The chapter discusses inherent trade-offs faced based upon the requirements and different connectivity options. Finally, this chapter also explores the future evolution of infotainment, telematics and other connected car services.

3.1 The general automotive industry context

Figure 12. Basic Automotive Industrial Principles

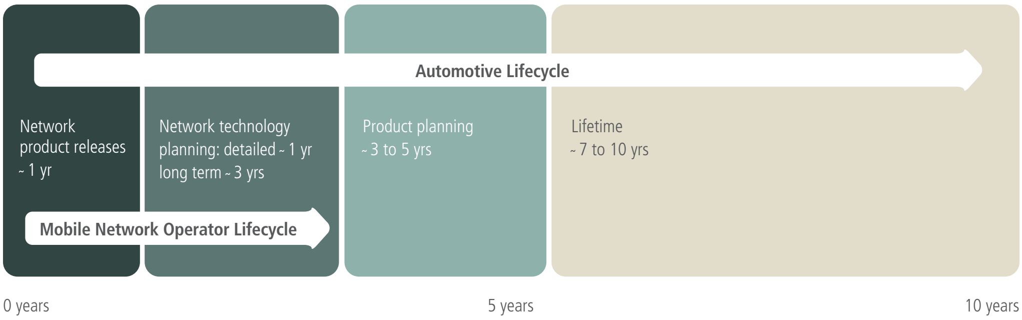


Source: GSMA 2012

Automakers have very different industrial requirements from mobile network operators. These differences help to explain some of the underlying challenges in cooperation.

One of the primary differences includes the very different lifecycles for the development of automotive products (≈3 to 5 years) and the lifetime of the products (≈7 to 10 years), as compared to the mobile operator lifecycle for the development of products (≈average of 6 to 12 months).

Figure 13. Differences in the Automotive and Operator Industrial Lifecycles



Source: GSMA 2012

These basic lifecycle requirements of the automotive industry mean it is necessary to:

- Create durable solutions, which:
  - require few hardware updates (given the difficulty to provide these updates across large number of dispersed users with embedded solutions).
  - request over-the-air updates for systems and services, in order to ensure that the device always functions appropriately for the duration of the network topology.
- Create interoperable solutions, which can move across brands and models, as well as provide economies of scale wherever possible (even across automakers).
- Manage multiple connectivity approaches in a more flexible manner to accommodate potential changes in user services during the lifecycle of the vehicle (changes of owners, countries of operation, etc.) as well as to have improved management of the overall base for telematics monitoring vehicle data (such as remote diagnostics).

Additional important contextual elements include:

- Specific regulatory aspects, affecting the connectivity solution (such as the European eCall and roaming requirements (see next section))
- Underlying business models for automotive sector

Examples of upcoming connectivity regulations in automotive

eCall

The European Commission is in the process of introducing a pan-European in-vehicle emergency service (eCall)[6] regulation in Europe, which will require:

- All new cars manufactured or distributed in the EU from 2015 to have an eCall in-vehicle system (with a network access device and UICC).
- All member states to indicate the most appropriate public safety answering point to route eCalls and to draw up detailed rules for public mobile network operators.
- All mobile network operators in Europe to handle an eCall like any other call to the single European emergency number 112 (by 31 December 2014).

This regulation, which will change the landscape in the EU, will result in wide-scale usage of connected vehicles in Europe.

6 eCall Definition from the Pan-European eCall Implementation Guidelines Draft v3.0 (2012, Task Force GUID): In case of a serious accident, the vehicle systems will automatically initiate a 112 call to the most appropriate Public Safety Answering Point (PSAP), which will establish a voice contact between the PSAP and the occupants of the vehicle, while, as soon as the connection is established, sending a minimum set of data (MSD) related to the accident including accurate location, time and direction of the vehicle to the PSAP. eCall can also be triggered manually.

European Roaming Regulation

Currently, the European Roaming Regulation is under review, as the current regulation expires in June 2012. The current proposals under discussion for the new regulation (which are driven by the consumer handset market) include:

- The introduction of "structural changes" or "structural measures", focused on stimulating competition by making it easier for alternative operators (e.g. mobile virtual network operators) to enter the roaming market and offer consumers alternative roaming tariffs.
- Potential decoupling ("unbundling") of roaming services from domestic services to allow for a separate sale of roaming services (from 2014).
- Potential wholesale roaming access: all mobile network operators would be obliged to meet "all reasonable requests for wholesale roaming access" (from July 2012).
- Reductions in retail and wholesale price caps and the extension of these caps to retail data roaming services.
- Review of the implementation in 2015.

The exact implications of the potential legislation on automotive services are not evident at this point; however, the pressure to reduce roaming costs in the EU is clear.

3.2 What are the connectivity options for automakers?

A number of options exist to connect a vehicle, including:

- **Embedded:** both the connectivity (modem and UICC) and intelligence is built directly into the vehicle;
- **Tethered:** connectivity is provided through external modems (via wired, Bluetooth or WiFi connections and / or UICCs), while the intelligence remains embedded in the vehicle;
- **Integrated:** connectivity is based upon integration between the vehicle and the owner's handset, in which all communication modules, UICC, and intelligence remains strictly on the phone. The human machine interface (HMI) generally remains in the vehicle (but not always).

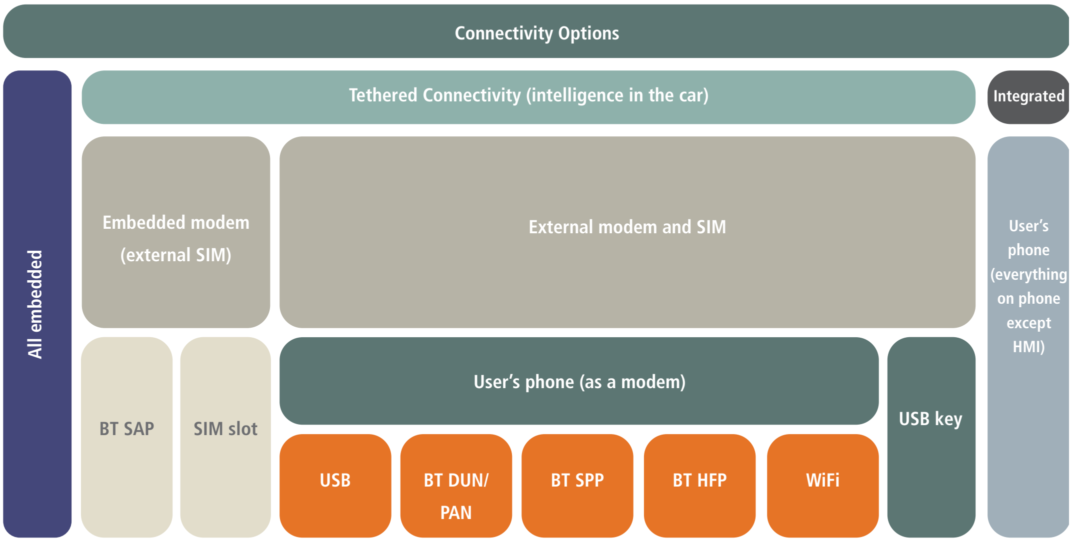
Figure 14. Comparing Different Types of Car Connectivity

	Embedded	Tethered	Integrated
Modem	Embedded	Brought-in	Brought-in
UICC ("SIM")	Embedded	Embedded/Brought-in	Brought-in
Intelligence/ Applications	Embedded	Embedded	Brought-in
User Interface	Vehicle HMI	Vehicle HMI	Projection of phone interface on vehicle display OR Remains directly on Phone

Source: GSMA 2012

Each of these different connectivity options relies upon different mechanisms for linking the car to cellular technology. The primary options are summarised in the following figure:

Figure 15. Car Connectivity Options



Source: SBD 2011

The utilisation of these different connectivity options is different across the various services:

- Integrated solutions tend to be used for higher bandwidth and personalised apps (such as on-demand music and social networking);
- Tethered solutions typically focus on connected navigation and internet-based infotainment features;
- Embedded solutions focus on vehicle-centric, high-reliability and high-availability apps (such as eCall and breakdown call services or bCall). Embedded solutions, covering a broad range of services, have generally been limited to premium vehicles, with some notable exceptions:
  - Volume brand manufacturers such as General Motors, Peugeot, Renault and Roewe with services available in entry models and up.
  - Where region-specific regulations exist for embedded solutions (such as eCall in Europe).

These three connectivity solutions are not mutually exclusive and can be used in tandem as appropriate for the proposed applications. Moreover, these solutions are likely to continue to co-exist in the future. A tandem approach might be used, for example, when the technology employed for the embedded system is likely to not be appropriate for newer-generation or higher bandwidth services.

These connectivity solutions also reflect the automakers' objective to differentiate between the:

- Costs for services that they are interested in bearing (such as remote diagnostics)
- Costs for large bandwidth, frequent use services (such as infotainment).

If this differentiation would be possible through split billing, automakers would likely reduce dramatically the employment of tethered solutions.

Embedded

All of the connectivity (module and SIM) and intelligence is built into the car.

Figure 16. Strengths, Weaknesses, Opportunities and Threats for Embedded Connectivity Solutions

Embedded Solutions

Strengths

- Seamless user experience
- Does not require user set-up
- Best communications performance, using single antenna
- Robust and reliable
- With an appropriate mounting location, suitable for both safety and security-related services (both crash resistent and attack resistent)
- Lack of problems due to incompatibly, interoperability or tethering issues
- Automaker can specify the internal modem and antenna according to the needs of the services to be offered
- Automaker can guarantee that the service and associated HMI is appropriate for use in-vehicle (and control the service's availability)

Weaknesses

- Existing solutions have prohibitive costs and logistics difficulties associated to changing operators during the lifetime of the vehicle
- Immediate significant hardware costs
- Limited technology evolution possible, without direct intervention
- Current difficulty to conduct split billing so that communication costs can be divided by services type and to the different beneficiaries
- Difficulty in agreeing upon roaming context in which users do not suffer sticker shock for "hidden" services. This fear of sticker shock results in some services being disabled pre-emptively by the driver

Opportunities

- Regulatory changes focused on increasing safety and security are resulting in mandatory regional deployments: opportunity for additional services to be offered on the selected technology
- Technological performance criteria for certain services may be reduced through the use of web-based apps, allowing embedded solutions to provide competitive solutions
- Increased operator provision of diversified billing options, as well as more Automaker direct management of the provisioning process is likely to be an important enabler for embedded solutions given the inherent improved user experience and reliability
- Operators could develop specific commercial offers for connected car services

Threats

- Given regional network evolution uncertain, hardware investments risk becoming will be outdated during the vehicle lifetime
- Depending on the billing model, the automakers and/or the operator's relationship with the final client may not be evident
- Operators could develop specific offers for telematics and infotainment services where connected car traffic is identifiable

Source: GSMA 2012

Certain services are particularly appropriate for embedded solutions, such as security and safety. These services need to be highly reliable, "always-on", and seamless for the end-user (as opposed to a primary risk of tethered solutions where the driver may forget to bring and connect his phone, for example).

Tethered

Tethered solutions rely on the intelligence of the application running in the car, while the user's SIM, phone or USB key is used to enable connectivity. Multiple ways to achieve tethering include:

- Embedded modem, which employs the user's existing SIM (via the Bluetooth SAP profile[7] or a SIM SLOT) solely for connectivity;
- External modem, which utilises the user's phone (via USB cables, Bluetooth profiles (DUN/PAN, SPP/HFP) or WiFi) or USB key tethering for both the connectivity and the modem[8].

Figure 17. Strengths, Weaknesses, Opportunities and Threats for Tethered Connectivity Solutions (Embedded Modem with Intelligence in the Car)

Tethered Solutions: Embedded Modem (BT SAP or SIM Slot)

Strengths

- Robust communication using vehicle antenna and modem, specified according to automaker requirements
- Ongoing communication charges are directly connected to the end-user's SIM
- Simpler deployment since no operator negotiations for roaming and billing required
- BT SAP: Improved battery life for user's phone (BT SAP places the device into the power-save mode)
- SIM-Slot: Reliable connection to SIM not dependent on wireless link
- Appropriateness of in-car services and (availability of the services) is easy to control given that the intelligence remains on the vehicle (as compared to integrated solutions).

Weaknesses

- Limited cost savings for vehicle hardware compared with fully embedded solution
- As with embedded solutions, limited technology evolution possible, without direct intervention
- BT SAP: protocol is not fully supported, even in new phones (some operators may block SAP for security reasons)
- BT SAP: Relies on the user's phone being in vehicle so it is not a reliable solution (in general) and, in particular, for safety and security related services.
- SIM Slot: Requires drivers/users to have an additional SIM for their vehicle

Opportunities

- Operators could develop specific offers for telematics & infotainment offers where connected car traffic is identifiable

Threats

- SIM slot: can be risk for thieves
- Regional network evolution uncertain, risking that hardware investments will be outdated during the vehicle lifetime
- Some operators discourage or prevent the use of mobile phones for tethering purposes (due to concerns of abuse regarding all inclusive data plans)
- Differences in charges between voice and data components of user plans can cause sticker shock for vehicle services

Source: GSMA 2012

7 **BT SAP (SIM Access Profile)** ~ A Bluetooth profile that makes a temporary copy of the SIM credentials from one device to another (e.g. copy the SIM from a handset to an embedded modem in a car).

8 **BT DUN (Dial-Up Networking)** ~ A Bluetooth profile that allows a connected device to make a data connection via the phone.
BT PAN (Personal Area Networking) ~ A Bluetooth profile that allows one or more connected devices to share the phone's connection to the internet
BT SPP (Serial Port Profile) ~ A solution that uses compatible apps (on the phone and in the car) to bypass tethering restrictions. Data is downloaded from the Internet to the app on the phone, from where it is side-loaded to the car using SPP.
BT HFP (Hands Free Profile) ~ This profile is used to enable a voice call that the car can then use to transfer very small amounts of data using in-band modem technology (data-over-voice).
USB cable ~ A wired solution that connects the phone to a USB connection in the car
WiFi ~ The car is able to connect to the Internet over WiFi if the phone is put into a portable hotspot mode.

This tethered approach, using an embedded modem, is often employed for user-based services (such as infotainment), as it enables the user to directly manage and pay the costs of the used services. It remains an unreliable solution for safety and security solutions, given the reliance on the user activating their phone or inserting their SIM.

Figure 18. Strengths, Weaknesses, Opportunities and Threats for Tethered Connectivity Solutions (External Modem and Intelligence in the Car)

Tethered: External Modem

Strengths

- Up-front hardware costs in vehicle are reduced
- Communication costs are directly tied to user
- Solution follows handset device evolution (higher replacement rate); therefore, more likely to be inline with network technology upgrades (avoiding obsolescence and, therefore, likely to provide faster performance as it becomes available)
- Direct links (USB Cables, or Sticks) also avoid the difficulties of having to use wireless protocols
- When USB modems are used, allows for data and voice (on the user phone) to be used in parallel, as well as likely to provide higher data transfer rates
- User's mobile phone can be charged whilst in use
- In an emergency where a second radio is not available, the USB could provide failover and support to the car systems
- Appropriateness of in-car services and (availability of the services) is easy to control given that the intelligence remains on the vehicle (as compared to integrated solutions)

Weaknesses

- Protocols are not seamless for tethering (user experience can be sacrificed)
- Appropriate profiles for different protocols are not universal across devices. Furthermore, software in telematics control unit must be developed to interface with different types of mobiles phones
- Communications module not likely to be automotive grade, reducing reliability and performance (particularly critical for safety and security)
- Antenna performance likely to be worse than embedded solutions
- Associated errors are likely to be attributed to the automaker, even when related to external modem device
- Tethered solutions can suffer from compatibility with SMS-based services
- Operators are not able to create specific offers for connected car services run through phones

Opportunities

- Additional services can be embedded into a USB key to include apps, maps etc. that streamline download and usability issues
- Operators could develop specific offers for connected car services (dedicated USB connections)

Threats

- Durability of the connection interface could be a problem for long term solution
- Some operators discourage or prevent the use of mobile phones for tethering purposes (due to concerns of abuse regarding all-inclusive data plans)
- Differences in charges between voice and data components of user plans can cause bill shock for vehicle services

Source: GSMA 2012

This tethered solution, using an external modem, has the benefit that:

- less costly hardware in-vehicle is required and
- the external modem is more likely to be up-to-date (given the higher replacement rate of handsets).

This solution however requires that the different protocols are universal across devices. Furthermore, it remains inappropriate for safety and security services, as no guarantee exists that the driver will use this solution consistently.

Integrated connectivity

The phone and the vehicle form an integrated solution with the communications module, SIM, and intelligence all provided by the phone. This solution generally relies on the HMI being provided by the vehicle (although it sometimes remains on the phone).

Figure 19. Strengths, Weaknesses, Opportunities and Threats for Smartphone Integration Connectivity Solutions (only HMI runs on the car, everything else is on the phone)

Smart Phone Integration

Strengths

- Connectivity costs are completely tied to driver (more likely to understand data plan implications)
- Allows for car connectivity to take advantage of the most recent device modules (i.e. the driver's most recent) and relevant network technology evolutions
- Allows for diversified infotainment options per driver
- Virtually no hardware start-up costs for services

Weaknesses

- Seamlessness of service is not guaranteed, as different profiles and protocols are not universally available
- Uncertainty of user experience
- Not appropriate for security and safety applications
- Not appropriate for vehicle based systems given the lack of guaranteed consistency in usage
- Driver distraction issues are difficult to manage/influence when external devices are used in the vehicle
- Antenna performance likely to be worse than embedded solutions
- Operators are not able to create specific offers for connected car services run through phones

Opportunities

- As the cloud becomes a primary receptacle for personalised infotainment content, integration can provide an appropriate means to access this content

Threats

- Regulations on driver distraction could limit the ability to use phones for in-motion services

Source: GSMA 2012

The integration approach is particularly useful for user-based services such as infotainment, in the technologies likelihood to remain up-to-date and in the direct allocation of services costs to the end user. It remains a solution often considered to be risky given the limited control the automaker's have on the applications and services used. It is also an unreliable solution for safety and security solutions, given the reliance on the user activating their phone.

Dealing with the trade-offs of the different connectivity choices

In practice, most automakers are likely to take a hybrid approach to connectivity rather than a one-size-fits-all solution. This means that they may, for example, adopt an embedded solution on their high-end models, a tethered approach on their entry-level vehicles, whilst offering an integrated smartphone product across all their vehicles.

In addition, the different approaches can be used in a complementary fashion in the same vehicles. An increasing number of vehicle manufacturers have launched smartphone integration solutions in recent months, with the main focus being on providing the driver with access to internet radio and social networking apps running on their smartphones. This trend will continue into the future, as manufacturers take advantage of the computing power and personalisation capabilities inherent in a solution that uses the customer's smartphone.

In parallel, however, most automakers will continue to keep some intelligence and applications in the car, and this is where they face the choice between embedded and brought-in connectivity. As described elsewhere in this report, the management of data costs is a significant barrier to using an embedded SIM for features with unpredictable data requirements and/or usage. Concern about this issue has resulted in increased interest in tethered solutions.

Automakers around the world have already experimented with most tethered solutions:

- Audi supports BT SAP,
- BMW and Mercedes use BT DUN and/or PAN,
- Toyota and Ford use BT SPP and HFP respectively in the USA, whilst
- Honda has adopted a USB dongle in Japan.

These solutions are characterised by the pros and cons outlined above, but there is some agreement across automakers that the following two tethered solutions will be the most important going forward:

- **Bluetooth DUN/PAN**: Bluetooth has a high penetration across most mobile phone market segments. Experts recommend the use of PAN, but automakers will continue to support DUN to ensure that highest levels of compatibility;
- **WiFi**: Most smartphones are now equipped with WiFi, and many consumers are already very familiar with the process for connecting their portable devices to a WiFi network.

The prioritisation of these two technologies for tethering is an important first step by the automakers, but they now face the challenge of optimising network usability for their customers.

The obstacles to successful tethering

To be successful, tethering for in-vehicle connectivity requires seamless service delivery across multiple devices. The necessary profiles and protocols, therefore, need to be available on all devices.

A further potential obstacle is the policies of some mobile operators to contractually prohibit tethering (whereas others permit the functionality as long as the customer pays an additional fee to enable tethering). These restrictions are generally a legacy of the all-you-can-eat data tariffs that mobile operators used to kick-start the mass adoption of smartphones.

The emergence of tiered-pricing plans provides an opportunity to evaluate the best approach to ensure an equitable, appropriate policy towards tethering.

Automakers are eager to address these issues so that tethering can become a more successful option for increasing car connectivity.

3.3 Automakers' business models for telematics

The vast majority of automakers have implemented a Business-to-Consumer (B2C) business model for telematics. This means that they charge the customer for the costs of providing the in-car system and the services. In some cases this requires the customer to make a single up-front payment when they purchase their car, but in other cases this involves the vehicle manufacturer charging an annual subscription fee.

Automakers are also exploring alternative business models including subsidies, advertising and additional Business-to-Business (B2B) services. Furthermore, some automakers are evaluating the economic sustainability of their services by taking into consideration the internal benefits derived from the services (such as customer loyalty). Nonetheless, such solutions are either still under investigation and generally only contribute a small amount to the overall business case.

Historically, automakers generally have charged customers an annual subscription after a free period. However, experience across many markets suggests that most customers are not willing to pay a subscription for telematics. The main exception to this appears to be the U.S., where an annual subscription is the dominant business model. By contrast, the evidence from Europe and other global markets suggests that automakers will struggle to make a subscription-based model work.

As a consequence, many automakers are now focusing on the single upfront payment business model, and in particular, on reducing the cost of equipping their cars with telematics. These cost reduction activities cover all parts of the automakers' value chain, but the two that have the most direct impact on mobile operators are the:

- management of data costs, and
- decision on which network access technology to adopt.

The management of connectivity-related service costs

Many existing automakers' business models place a strong emphasis on ensuring that data costs remain as low as possible, so that they can provide customers with lifetime access to the majority of services. This approach raises multiple issues and questions:

- How much data connectivity is needed for services?
- Who should be the appropriate owner of the service costs?
- What is the appropriate pricing for these services (the perceived value of the service versus willingness to pay)?
- How to ensure that the appropriate charges are billed for services?

Figure 20. Automotive Considerations in Managing Cost of Data-Related Services

Source: GSMA 2012

Due to the difficulty in meeting the challenges of developing a robust business model, many automakers are turning towards tethering and smartphone integration to enable connectivity in the car i.e. ensuring that the user pays directly for the more data intensive and difficult-to-predict services.

However, some risk exists that these alternative solutions will result in customer dissatisfaction with ease-of-use and device compatibility. Many automakers have, therefore, expressed a strong interest in initiatives that will bring down the cost of data (and permanent roaming where applicable) to a level where services with a moderate data requirement (such as remote diagnostics, traffic information and connected navigation) can be provided through an embedded SIM with a single upfront payment for the lifetime of the car.

3.4 Choosing the right automotive module?

One of the hotly debated topics in the automotive industry regards the choice of the appropriate connectivity module to support telematics and infotainment services. This choice dictates the performance characteristics possible (with regards to those available in the relevant local network) as well as the level that the services are "future-proofed" to handle network evolutions.

Automakers need to weigh investment costs (given the current limited revenues generated by embedded telematics and infotainment services) against the potentially much greater costs (and difficulties) of retrofitting a new solution on a vehicle post-production. Retrofitting solutions are employed when new technologies are required for the service or, for example, in the case of a network generational switch-off.

Moreover, automakers must balance the need to support:

- basic services and connectivity that all operators provide against;
- national, regional or global 'best-in-class' connectivity, to enable the consumer to have the best experience possible if they choose to (based on network choice and/or subscription plan).

Furthermore, the automotive industry has a long tradition of very specific requirements with respect to product quality, support and delivery processes. Additionally, a need exists for special automotive functionalities, as well as a high level of robustness and durability. The availability of the relevant embedded module needs to correspond with the typical automotive lifecycle, which has an impact on the module component sourcing and the service processes. These additional aspects are reflected in a higher average selling price for automotive modules than is typical in the general consumer electronics market.

Criteria affecting automotive-grade module costs

Key aspects, which influence the cost of automotive-grade modules (as compared to consumer electronics modules), are listed below:

- Quality and reliability, compliant with the requirements of the automotive industry
  - Processes according to common automotive standards
  - Defined product quality (delivery and field performance)
  - Automotive-compliant manufacturing
  - Advanced test reports and traceability
- Robustness & extended performance
  - Extended temperature range
  - Extended shock resistance
  - Automotive-compliant mounting technology
  - Radio frequency connectors matching automotive requirements
- Enhanced product offering
  - Product enhancements (higher grade components and special mechanics)
  - Automotive-specific features
  - Over-the-air updating, with management features to control quality of update
  - Flexible building blocks and customisation options
  - Variants for specific regions
- Lifecycle management
  - Product availability: meeting extended lifecycles of the automotive industry
  - Technology transition: upgrading to next generation technology, variants with different technologies
  - Component sourcing (according to automotive requirements)
  - Ease of software updates
  - Product support over the lifecycle of the automotive industry

Expected price evolutions for modules

Based upon the additional requirements to ensure successful implementation of embedded cellular connectivity in the automotive industry, some general indications with regards to the evolution of module costs is provided below.

Figure 21. Cellular module core technology market prices: (in US$)[9]

Automotive Module Technology	2011	2013	2015
2G	30	25	20
2G/3G (and CDMA EVDO)	65	59	55
LTE/3G/2G	N/A	120-150[10]	80

Source: GSMA 2012

Factors Impacting the Evolution of Automotive-Grade Modules

The following factors will play a role in the cost evolution of modules:

- 2G module costs will continue to decline marginally over time, but no major reductions are expected on existing cost levels.
- 3G module costs are expected to continue to decrease over time, but the level of reductions are tapering out.

9 The above table shows the average price for a basic automotive platform, which has additional requirements over normal industrial M2M modules, based upon estimates made at end of 2011. The pricing does not cover extensions and customizations of the modules, which are typically required to meet the requirements of individual projects, such as: special features or functionalities; technology extensions; specific quality agreements; specific warranty agreements; extended delivery time / extended lifecycle; individual service level agreements; special band combinations / broad range of bands; special support and service

10 These are indicative prices for pilot/sample quantities, as volume projects in LTE are not expected in 2013.

- LTE automotive-grade modules are expected to decrease substantially from their initial price offering, following a depreciation curve similar to that of 3G (average market price erosion generally above 10% a year with peaks of more than 20%[11]). The speed of this decrease will depend upon the economies of scale from extensive demand for the modules (dependent upon widespread deployment of LTE networks).
- The actual cost of modules depends on order sizes with discounts for volume.
- Generally, automotive modules include backwards-compatible generational technology – therefore, the first LTE modules will generally include 2G and 3G. When regional coverage becomes more even (and so fewer mobile technology generations are required), the LTE modules will be less expensive due to a reduction in the inclusion of some air interfaces.

Assessing the costs of modules

It is important to recognise that automotive module costs are only one element of the total costs of ownership for embedded mobile services; in fact, the overall costs include:

- Communications module
- Design and integration
- Distribution and installation
- Systems and platforms
- Network traffic costs
- Field tests

Analysys Mason's Report The Total Cost Of Ownership For Embedded Mobile Devices, (11 November 2010, Reference 17974-455) found that the module and associated network traffic represent only:

- 17% of the total cost of ownership for embedded 3G devices, and
- 9% of the total cost of ownership for embedded 2G devices.

These percentages are even lower for transport applications with communications modules accounting for an average of 5% of the total cost, given the important role of design and provisioning in this market [12].

Choosing an appropriate module

Clearly, automakers have to account for a large number of considerations when selecting the most appropriate communications technology to include in vehicles directly (embedded) and what/if to tether.

The decision-tree for selecting a technology is generally based upon:

- Services to be provided
- Regional technologies available
- The match between the services and the most appropriate regional technologies (including eventual switch-off timelines)
- Target total costs of ownership of the solution (including maintenance)
- Required duration of solutions (i.e. long life duration and capability to be able to provide the components for 10 years minimum)
- Sustainability of the form factors
- Power consumption performance
- Size of the solution (in many cases, the device must be very small)

11 Analysys Mason, Berg Insight, ABI "Mobile Connectivity: Comms Module Price Development"
12 Analysys Mason's Report on The Total Cost Of Ownership For Embedded Mobile Devices, (11 November 2010, Reference 17974-455), page 19.

Clearly, automakers should make the appropriate selection from the beginning to avoid:

- Retrofit costs (generally more than €100)
- Difficulty in upgrading modules (requires a visit to the mechanic)
- Perceived instability of service solutions.

Why is the module choice so important?

As mentioned previously, great pressure exists to reduce costs for telematics and infotainment services. Furthermore, automakers seek a stable mono-mode hardware solution for most markets, which could be guaranteed for 15 years. Given the very different cellular network deployment statuses and evolution paths possible, this objective, while understandable, is difficult to achieve.

European eCall: Hardware Quandary

Automakers selling cars in Europe face a specific network access technology issue when planning their response to the proposed legislation that will require them to fit eCall to all cars that are "Type Approved" from 2015. According purely to the technology requirements of the regulation, automakers could simply select 2G as the preferred access technology for an eCall-only system.

The majority of cars that are sold in 2015, however, can reasonably be expected to still be on the road in 2025, and many even through to 2030 and beyond. Therefore, the critical question for automakers is which network access technologies will still be operational in all European countries in the period between 2025 and 2030?

European mobile operators are not in a position to provide the desired guarantees about the future availability of 2G in Europe for several reasons (as outlined earlier in the section Network evolution is difficult to predict). European automakers are therefore faced with the difficult task of deciding between;

- a lower cost 2G-only device, with the risk that it may not remain operable for the lifetime of the car, and
- a higher cost 2G/3G device, which offers a greater likelihood of functioning at the end of this period.

The reality is that some automakers will adopt the lowest possible cost approach to satisfying the eCall legislation, and hence they will fit cars with a 2G device from 2015. This leads to unanswered questions about what fall-out will exist if an eCall system does not work in the future because its network technology is no longer available.

How tethering can support embedded connectivity choices

One way for automakers to manage the data transmission costs is to transfer some, or all, of the responsibility for paying these costs to the customer. Currently, the most popular solution is to use a Bluetooth tethering connection to the customer's mobile phone, but this introduces ease-of-use issues and concerns regarding device compatibility (as outlined above).

3.5 The automotive use cases for provisioning and connectivity (as defined by automakers)

The use cases for automotive connectivity embrace a variety of situations, with primary distinctions being made according to:

- who pays the connectivity contract and
- the frequency of modifications to the connectivity use case.

The primary automaker use cases, as outlined by automakers in the Connected Car Forum, are presented below:

Figure 22. Automaker Use Cases for Connectivity

Process	Connectivity Use Case	Use Case Characteristics		
		Description	Owner of Connectivity Contract	Expected Frequency of Use Case
Vehicle Testing	Test and development of Telematics Services	Allows Automaker to easily test different SIMs in the same car and the same Telematics Control Unit (TCU)	All Possibilities	Varied
Vehicle Delivery	Initial Vehicle Production where Automaker pays for Telematics	SIM is provisioned to the Operator according to the vehicle destination	Automaker Service Contract	Once
Service Activation: Consumer	Vehicle sale where services are paid by vehicle owner	SIM is provisioned to the customer's Operator when the vehicle is sold	Customer Contract	Once
Connected Car Service Operation:				
Automaker Connectivity Contractual Changes: Small Scale	Vehicle moves permanently to new region where Automaker pays for Telematics	Automaker can provision SIM to their local Operator	Automaker Service Contract	Infrequent
Automaker Connectivity Contractual Changes: Frequent	In order to maximise performance characteristics (i.e. signal strength, cost, application package, etc.), connectivity is switched across operators domestically. Ex. Car is within Country A and is switching Operators according to defined parameters (e.g. signal strength, cost, application package)	Automaker can provision SIM to their local Operator	Automaker Service Contract	Every second/minute
	Traveller Roaming: Car is travelling temporarily from Country A to Country B. Subscription is changed from local Operator in Country A to local Operator in country B	Automaker can provision SIM to their local Operator	Automaker Service Contract	Every hour/day/week
Customer Service Changes	Vehicle Owner changes Operator (where owner pays for telematics services)	Customer can provision SIM to their new Operator	Customer Contract/ Automaker Service Contract	Every 1-2 years
	Car is sold to a new owner (where owner pays for telematics services)	New owner can provision SIM to their Operator	Customer Contract/ Automaker Service Contract	Every 3-4 years
	Car is driven by a new driver (where owner pays for telematics services); This use case is particularly interesting for car sharing programmes	New driver can provision SIM to their Operator	Customer Contract/ Automaker Service Contract	Every hour/day/ week
Service Cancellation	Service Subscription is stopped	Automaker or Customer can cancel subscription	All Possibilities	Infrequent
Hardware Changes	Operational Problem: Telematics Control Unit fails	SIM in new TCU can be provisioned to same Operator as used in the failed TCU	All Possibilities	Once
	Refitting of Telematics Control Unit	SIM in the refitted TCU can be provisioned to a relevant Operator as required	All Possibilities	Once
Revision of Large Scale Connectivity Strategy	Automaker changes Operator (e.g. for commercial reasons)	Automaker can provision the SIM no a new Operator	Automaker Service Contract	Very Infrequent
	Automaker changes business model (i.e. who pays for connectivity)	Automaker can change business model or offer free period by provisioning SIM from its Operator to/from the customer's Operator (i.e Transfer Subscription)	Automaker Service Contract	Infrequent
	Operator Merger/Purchase: Operator A is merged with Operator B. Automaker is currently with Operator B. Automaker changes subscription from Operator B to preferred Operator X since involvement of Operator A is not seen as beneficial	Automaker can provision SIM to new Operator	Automaker Service Contract	Very Infrequent
	Automaker Company Purchase: Automaker A buys Automaker B or brand from Automaker B. Subscription for bought Automaker B needs to be changed to Operator from Automaker A	Automaker can provision SIM to new Operator	Automaker Service Contract	Very Infrequent
	Initial Operator goes out of business where Automaker pays for Telematics	Automaker can provision SIM to new Operator	Automaker Service Contract	Very Infrequent

Source: GSMA 2012

These use cases represent the current and emerging needs of automakers. Further use cases are likely to evolve, for example, as car sharing becomes more widespread. Cases, in which the owner and the driver of a car are not related, are likely to become more important in the future, further underlining the importance of managing who pays for the telematics services.

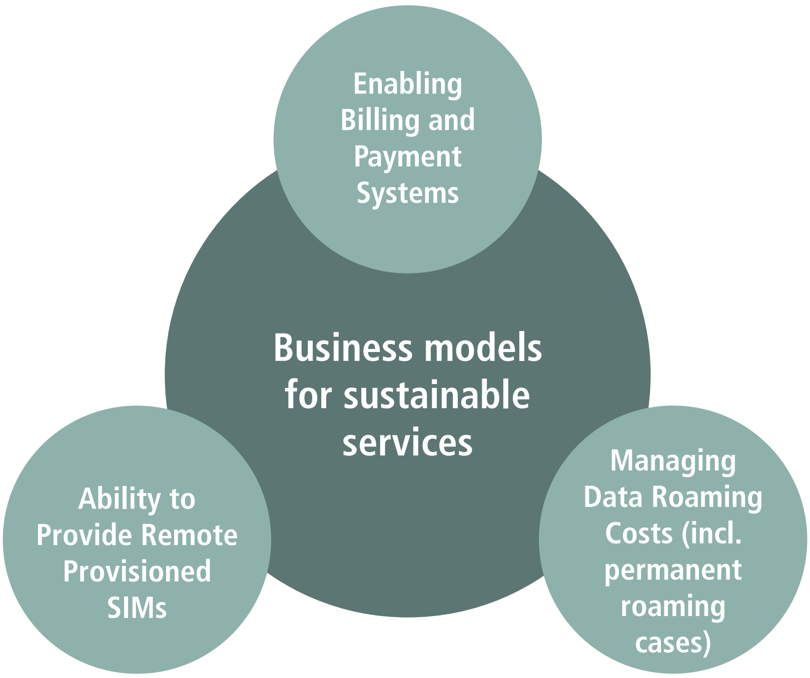
The key underlying enablers for automotive connectivity

The automotive use cases for connectivity underline the outstanding need to identify business models for sustainable services, which can respond to the connectivity demands of users and the desired service levels of automakers.

Three factors play a key role in enabling these business models:

- The ability to manage data roaming costs
- The availability of enabling billing and payment systems
- The ability to provide remote-provisioned SIMs

Figure 23. Important Role of Enablers in Supporting Business Models for Telematics and Infotainment Services



Source: GSMA 2012

Roaming

Roaming is an essential element of any automotive application, reflecting the:

- Distinctive connectivity arrangements in the automotive market in which country-specific SIMs are generally not used. Vehicle manufacturers typically source their SIMs from a single mobile operator for a given region. In some cases these SIMs are registered on the home location register (the HLR) of an operator with an actual radio network, but in other cases they may be sourced from a mobile virtual network operator (MVNO) or third party service provider that does not have its own radio network. This means that the SIMs are either permanently, or almost permanently, roaming, regardless of where the car was produced or sold.

- Viability of services in a moving vehicle (which by definition could cross network operator boundaries).

As a result, the management of data roaming costs is vitally important to the automakers' business case.

Billing and payment systems

Billing and payment systems are a critical element for all automotive service deployments, today and for the future, especially as different business models are tested. Within the Connected Car Forum, four primary types of billing have been raised by automakers to unlock the potential for telematics and infotainment business models (see the following figure).

Figure 24. Four Types of Billing Desired by Automakers

Service Billing: being able to allocate cost based upon a per-service basis, in order to charge back to the service owner

Split Billing: being able to allocate cost against a service or a location or a time of day

End User Billing: being able to provide cost allocation to the end user or interact with other payment methods

Retail Billing: being able to add charges for other items to an existing billing relationship

Source: GSMA 2012

Split billing and service billing are clearly critical enablers for infotainment services and in-car applications, with regards to:

- providing the flexibility to split services across different beneficiaries, as well as
- responding to end users' preferred payment approach (including pay-as-you-go versus. subscription; consolidated billing for multiple services versus new bills).

Automakers require that split services enable:

- data for vehicle-related (and potentially connected navigation) services to be billed to them directly, through an embedded SIM that they fund for the life of the car;
- other services, including infotainment, to be billed directly to the customer, preferably through the same embedded SIM (either by linking it to the customer's personal mobile operator contract or through the provider of the embedded SIM having a direct billing relationship with the customer).

Interestingly, this missing functionality is considered so important by automakers that they have relied on tethering as a workaround for service billing.

Remotely-provisioned SIM

The ability for automakers to re-provision their SIMs would change the current ecosystem. The next generation embedded SIM would help to overcome a number of existing problems, outlined in the previous automotive connectivity use cases, including late-stage provisioning for vehicles depending upon where the vehicles will be operational.

The primary open areas related to connectivity use cases & enablers

Many of the automaker-defined use cases for connectivity are likely to be robustly supported by the reprogrammable SIM functionalities under development. This functionality, however, has not been designed to address three potential automotive use cases:

- Frequent changes in connectivity between operators, in order to maximise performance characteristics (i.e. signal strength, cost, application package, etc.). For example, a car within country A switches mobile operators according to defined parameters (e.g. signal strength, cost, application package).
- Traveller roaming: A car is travelling temporarily from country A to country B. The subscription is changed from local mobile operator in country A to a local operator in country B.
- Frequent changes of operators for certain services attached to each new driver: each new driver pays for their portion of infotainment services (while the owner pays for telematics services). This use case is particularly interesting for car sharing programmes.

Importantly, these use cases clearly reflect specific automotive requirements related to underlying roaming and billing issues, as opposed to requirements for permanent changes between operators.

These use of the next generation embedded SIM to address these three use cases would likely:

- Be a workaround for these enabler requirements (as opposed to being a dedicated solution);
- Result in an undesirable end-user experience (as well as depending largely on the nature and conditions of the contracts established between the operators and automakers on a bilateral level).

3.6 Requirements related to specific services

The next section of this white paper analyses the primary categories of telematics (12 types) and infotainment (4 types) – see the following diagram. These services exist in various deployment forms across the globe, with telematics being more widely deployed than infotainment.

Figure 25. Primary Telematics and Infotainment Services

Telematics

- Navigation/Journey times/Augmented reality/Points of Interest
- Travel and Traffic Assistance (Assisted Traffic Regulation, Access Control/Parking Zone Management/Eco-Driving)
- Traffic Sign Warning
- Remote Control of Vehicle Environment/ Car Features/Restricted Drivers
- Remote Diagnostics
- Breakdown Services (bCall)
- General eCall (not EU specification)
- Insurance/Stolen Vehicle Tracking
- Fleet Management
- eFreight/Tracking and Tracing
- Payment/Ticketing/Metering/Tolling
- Electrical Vehicle Use Cases: Battery Charge Monitoring/Control/ Navigation to Recharge Points

Infotainment

- Radio - Music, News: On-Demand Real Time Content
- Video: On-Demand and Real-time Content
- Multimedia, Internet Services and More
- Other Infotainment Applications (Passenger Gaming)

Source: GSMA 2012

The general status of telematics and infotainment services today

The above figure outlines the range of telematics and infotainment services, which exist today. These services are evolving, in particular with the development of Internet-based in-car services and the explosion of apps in the consumer electronics sector.

The deployment of these automotive services is uneven across vehicle types, brands and regions:

- Telematics are offered across entry-level vehicles, mass-market vehicles, and premium vehicles. They tend to be considered **essential services for premium vehicles.**
- Infotainment is a current **differentiator for higher-end vehicles**, focusing on:
  - radio real-time content and
  - multimedia, internet services in a pervasive manner.

Specific service characteristics

The characteristics of the telematics and infotainment services show wide variation in relation to:

- **Nature of the services:** on-demand, push and pull;
- **Continuity of the demand for the service:** regular, cyclical and irregular;
- **Maximum potential frequency:** constantly throughout the day, several times per day, daily, occasionally;
- **Service delivery responsiveness:** real-time; near real-time; non real-time;
- **Transmission type:** the information, which is being exchanged: voice, data and voice and data. This information can vary greatly on the exact configuration of the service;
- **Bandwidth range:** the specific bandwidth ranges which the service would need to support.

Figure 26. Importance of Connectivity Criteria per Service

	Service Characteristics				Transmission Type		
Services	Type of Service	Continuity of Demand	Max. Potential Frequency	Service Delivery Responsiveness	Data	Voice & Data	Bandwidth Range
Radio-Music, News: On-Demand Real Time Content	On-Demand	Irregular	Several Times per Day	Real-Time	X		>64kbit/s
Video: On-Demand and real-time content	On-Demand	Irregular	Several Times per Day	Real-Time	X		>1Mbit/s
Multimedia, internet services and more	On-Demand	Irregular	Several Times per Day	Near Real-Time	X		>1Mbit/s
Navigation/ Journey times/ augmented reality points of interest	On-Demand	Irregular	Several Times per Day	Near Real-Time	X	X	<1Mbit/ usage
Travel and Traffic Assistance (Assisted Traffic Regulation, Access Control/Parking Zone Management/ Eco-Driving)	On-Demand	Irregular	Several Times per Day	Near Real-Time	X	X	<1Mbit/ usage
Remote Control of Vehicle Environment/ Car Features	On-Demand	Cyclical	Several Times	Near Real-Time	X	X	<1Mbit/ usage
Remote Diagnostics	Pull	Irregular	Daily	Non Real-Time	X		<1Mbit/ usage
Breakdown Services (bCall)	On-Demand/Pull	Irregular	Occasionally	Near Real-Time		X	<1Mbit/ usage
General eCall (not EU specification)	On-Demand	Irregular	Occasionally	Near Real-Time		X	<1Mbit/ usage
Insurance/Stolen Tracking	Pull	Regular	Several Times per Day	Near Real-Time	X		<1Mbit/ usage
Fleet Management	Pull	Regular	Constantly, Daily	Near Real-Time	X		<1Mbit/ usage
eFreight/ Tracking and Tracing	Pull	Regular	Constantly, Daily	Near Real-Time	X		<1Mbit/ usage
Payment/Ticketing	On-Demand	Irregular	Several Times per Day	Near Real-Time	X		<1Mbit/ usage
Electrical Vehicle Use Cases: Battery Charge Monitoring/ Control	Pull	Regular	Constantly, Daily	Near Real-Time	X		<1Mbit/ usage
Traffic Sign Warning[13]	Pull	Irregular	Several Times per Day	Near-Real-Time	X		<1Mbit/ usage

Source: GSMA 2012

13 Traffic sign recognition is a telematics service that connects an in-car camera to an off-board sign recognition system. Details of the recognised sign are then transmitted back to the car in real time for presenting to the driver. This is an evolution of the existing (non-telematics) on-board sign recognition systems that have a limited set of signs that can be recognised. The intention is to use the greater computing power of an off-board server to allow any sign in any country to be recognised.

What are automaker technology requirements for specific services?

Despite the differences in the nature of the services, seven criteria summarise the primary technological factors, which determine the appropriateness of different cellular network technologies for the deployment of each of the different telematics and infotainment services:

- **Wide coverage**: particularly important for all automotive services, since by definition vehicles are in movement across the territory; this movement also follows the road network and not necessarily the urban density (one of the primary factors governing network deployment).
- **High bandwidth**: generally an important factor for applications in consumer electronics, but it is of primary importance for infotainment.
- **Latency tolerance**: level of service sensitivity to delays in network responsiveness for data, voice and SMS transmission.
- **Service delivery responsiveness**: the speed of service considering the cumulative delay in the end-to-end service execution (including third party service elements). This criterion is important for some automotive applications, including primary safety critical applications and vehicle-to-infrastructure communication.
- **High security**: the network security for the transmitted information. Security is particularly important to automakers, given the necessity to avoid any risk to safety-critical applications electronically controlled in vehicles.
- **High reliability**: the dependability of the network, which is a dynamic function of network availability, the resilience of network to survive failure, service implementation (i.e. the way in which an individual service is built on top of the base network), and the technology of the different radio interfaces. Although important for all services by definition, it is mission-critical for safety and security applications.
- H**igh privacy**: the privacy of user information is generally important for all mobile services; however, automotive services have a particular sensitivity, given their emphasis on tracking the movement of individual vehicles, as well as potentially handling sensitive information (including breakdown information, payment data, etc.).

The following table outlines the primary importance of the different technology criteria (as described above) for the individual services. This importance is characterised as either:

- **Essential Constraining Criteria:** this criterion determines the suitability of the cellular network technology in supporting the individual service (i.e. the criterion which is most restrictive in the selection of appropriate network technology);
- **Very Important;**
- **Important.**

Figure 27. Primary Importance of Technology Criteria for Telematics and Infotainment Services

	Wide Coverage	High Bandwidth	Low Latency	High Security	High Reliability	High Privacy
Radio - Music, News: On-Demand Real Time Content	I	ECC	I		I	
Video: On-demand and Real-Time Content		ECC	I		I	
Multimedia, Internet Services and More		ECC	I			I
Navigation/Journey Times/ Augmented Reality Points of Interest	ECC	I				
Travel and Traffic Assistance (Assisted Traffic Regulation, Access Control/Parking Zone Management/Eco-Driving)	ECC					
Remote Control of Vehicle Environment/Car Features	ECC		I	VI		
Remote Diagnostics	ECC				I	I
Breakdown Services (bCall)	ECC			VI	VI	I
General eCall (not EU Specification)	ECC		VI		VI	I
Insurance/Stolen Tracking	ECC			VI	I	I
Fleet Management	ECC				I	I
eFreight/Tracking and Tracing	ECC				I	I
Payment/Ticketing	ECC			VI	I	VI
Electrical Vehicle Use Cases: Battery Charge Monitoring/ Control	ECC				I	
Traffic Sign Warning	ECC			VI	VI	I

Legend: ECC: Essential Constraining Criteria; I: Important; VI: Very Important

Source: GSMA 2012

The pattern of the different technology criteria with the relation to the individual services, illustrates:

- The primary role of coverage for all telematics services, and
- The primary role of bandwidth for all infotainment services.

Selecting the right technology for services, based upon bandwidth

Despite the variety of services and types of cellular technologies, a clear classification exists with regards to the requirements for bandwidth and latency:

- Most of today's telematics services can work appropriately with any 2G-network technology or higher.
- Infotainment services require more advanced network generations, i.e. HSPA (3.5G network technology) or higher to accommodate bandwidth and latency requirements.
- Navigation, journey times benefit from the additional bandwidth and lower latency provided by more advanced network technologies, i.e. EDGE (2.5G network technology or higher).

This classification captures the current dilemma relating to the selection of the most appropriate technology, i.e.: a wide variety of telematics services can be provided with older, more inexpensive technologies, but the emerging service categories (many based upon infotainment) require newer, higher bandwidth technologies.

Figure 28. Classification of Telematics and Infotainment Services by Bandwidth and Latency Requirements

Source: GSMA 2012

How to choose the right technology, based upon regional coverage

The other primary selection criterion, for deploying telematics and infotainment services, is regional network coverage. This criterion is fundamental for all automotive services and is the essential constraining criteria for most telematics services. The challenge, however, for the automotive sector is multifaceted, given:

- Multi-national vehicle production (resulting in the necessity to find a common technological denominator across different territories and often operator networks); and
- The extended duration required of the adopted solution (including the time from the hardware development decision to the vehicle production (3-5 years) compounded with the vehicle life expectancy (an average of 7-10 years), resulting in the necessity of a solution that lasts more than 10 years.).

Current coverage

As discussed, coverage varies significantly in the different regions of the world.

Today, 2G-network technology generally offers the widest coverage, and as such, has been a natural choice for many automakers for telematics services.

Considerations for the future of regional coverage

As discussed, the ability to forecast the evolution of cellular network technology is quite difficult for a variety of reasons.

The viability of 2G network technology as a solution for telematics services in some regions, such as Europe, is in question, due to the need to re-farm spectrum used for 2G services for LTE and LTE-Advanced; however, a large-scale deployment of mission-critical 2G technology will influence decisions on the viability and the commercial impact of switching-off 2G.

In the long term, continued demand for bandwidth will drive all regions towards LTE (and LTE-Advanced) so this network technology could be the future foundation for infotainment services (where the additional technical performance characteristics are particularly useful for the quality of the end service), as well as telematics. It is likely that HSPA and HSPA+ networks will continue to provide “next-best” mobile broadband connections.

The likely timeline for the viability of LTE varies by region, with aggressive roll-outs planned for:

- Developed Asia-Pacific
- North America
- Europe

Mass-market consumer uptake for LTE is expected by 2013 for the above geographies.

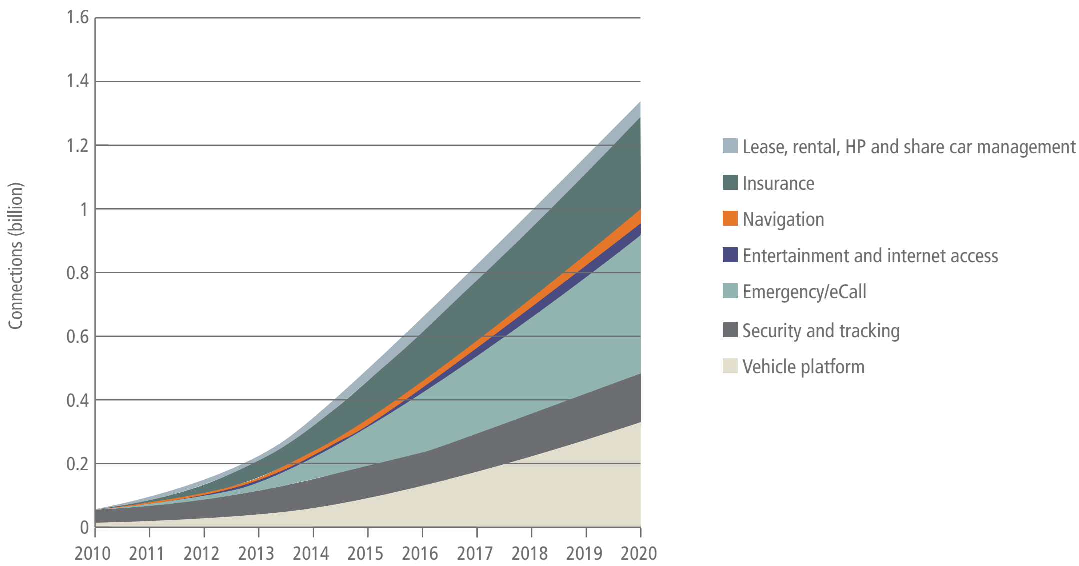
How telematics and infotainment services are evolving

All of the categories of telematics and infotainment services are expected to grow in the next decade.

For example, in 2011, Machina Research conducted a market sizing report (*Machine-to-Machine (M2M) Communication in the Automotive Sector 2010-20*), which forecast major growth in automotive services from 2010-2020[14]. Although this figure reflects the dominance of aftermarket devices on the market, it captures the exponential growth of the sector overall.

14 There forecasts include both vehicle platforms and aftermarket devices; the figures do not include applications that run solely on the vehicle platform such as the ‘voice’ and ‘manufacturer data’ categories given their lack of associated ‘connections’.

Figure 29. Automotive Forecast for Global M2M Connections[15]



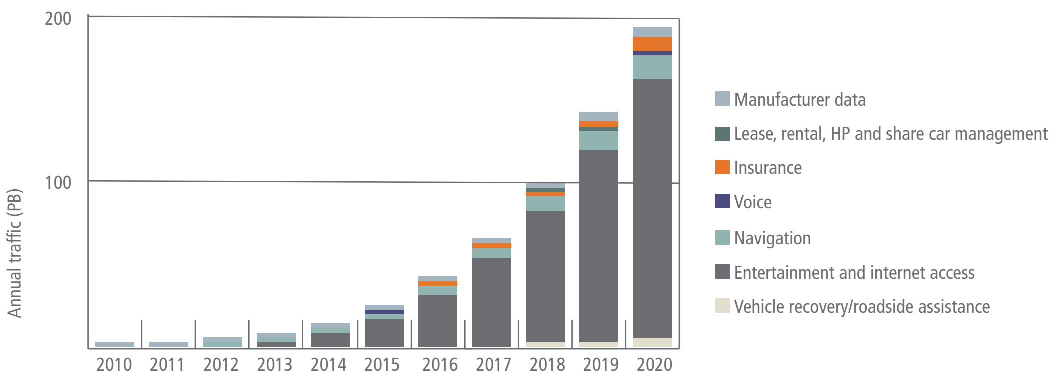
Source: Machina Research Forecast

Automakers indicate that:

- Telematics and infotainment will be offered across vehicle brands, with a critical mass on embedded solutions.
- Tethered solutions will continue, with a focus on providing upgradable solutions for technology and, hence, the higher bandwidth services, i.e. infotainment, high bandwidth apps (music & video).
- Embedded solutions will continue for vehicle-centric, high-reliability and availability apps (such as ecall and bcall).
- Infotainment and video services are expected to grow exponentially.

These affirmations are confirmed in recent forecasts, such as Machina. In fact, when analysing Machina's forecast for global wireless traffic generated by embedded mobility in the automotive sector, an exponential increase is due to entertainment and internet access.

Figure 30. Automotive Forecast for Global Wireless Traffic Generated by Embedded Mobility by Application



Source: Machina Research, 2011

15 Note: There are applications that run solely on the vehicle platform such as the 'voice' and 'manufacturer data' categories and therefore do not have associated 'connections'

Enabling Apps in the car

An additional priority for automakers is to enable an open environment that provides the driver with access to new and evolving functionality during their ownership of the car. This is in contrast to the current situation, where it is almost impossible to add features to a car after it has been produced.

In the short term, automakers are looking to **smartphone integration** as the first step to enable an open environment through Apps, with solutions already available/announced by BMW, Mercedes, Audi, Jaguar, GM, Ford, Toyota and Mini.

At present, there is little commonality in the technical solutions being offered to customers, although the services are focused on internet radio and social networking. Going forward, the industry standard MirrorLink[16] may provide some level of commonality across automakers, but the reality is that proprietary solutions are very likely to exist in parallel, creating a very fragmented industry.

The alternative approach is for automakers to embed an **open platform in the car** and for new Apps to be downloaded to the embedded system. Such solutions are starting to be rolled out by BMW, Mercedes, Renault, GM and PSA, but this is still quite an immature market. The challenges for automakers include deciding which operating system to adopt for their in-car platform, whether to wait for:

- a browser-based solution such as HTML5,
- the development of an App store-style environment for offering new Apps, and
- the business model.

The Connected Car Forum has had some initial discussions about whether mobile operators could use their App store experience and infrastructure to support the automakers with the implementation challenges that they face. However, a clear vision of what automakers may want to implement in the future has not emerged, and so this topic is a key issue for further investigation.

Cooperative Systems

Co-operative systems are systems (standardized in frame of EC M/453) based on:

- best use of access and transport technologies and
- the exchange of information among Intelligent Transport System (ITS) stations and back-end systems.

The current focus is on enabling cooperation between road hazard warning systems and ‘classical’ ITS applications. Road safety systems request the exchange of real/near real time information between:

- Vehicles (i.e. V2V and or V2I<=>I2V),
- Vehicles and infrastructure (i.e. I2V and V2I) and
- Infrastructure (i.e. I2I).

Historically, road hazard warning systems have relied on deployment of ad-hoc non-cellular technology. The use of mobile technologies, such as HSPA and LTE, have been studied and brought to standardisation as enabling technologies for the information exchange between:

- vehicles and infrastructure (V2I) and
- across infrastructure (I2I).

16 Mirrorlink – An industry standard that defines how a vehicle HMI can be used to display and control an application running on a smartphone, typically over a BT or USB cable connection

4. What Are the Next Steps?

This chapter explores how direct cooperation between automakers and mobile operators could overcome existing challenges in the connected car ecosystem. It summarises key recurrent topics suggested for joint cooperation during the course of the Connected Car Forum between June 2001 and December 2011. The chapter also suggests primary topics for future cooperation between automakers and mobile operators.

4.1 Preface

The further evolution of telematics and infotainment services depends on increased collaboration between automakers and mobile network operators. This evolution is particularly critical both given the sector's critical mass and the significant growth expected. To reach this potential, the stakeholders will need to cooperate to resolve the existing barriers and to develop new opportunities.

However, this collaboration needs to recognise that whilst the automotive industry has a product horizon of more than 15 years (i.e. 3-5 year development cycle, plus 7-10 year average vehicle lifetime); the mobile industry has been in existence for little more than 20 years in total. In that time, an evolution from GSM to UMTS to HSPA and now to LTE has taken place, accompanied with a shift from a pure voice service, through messaging, broadband internet browsing and now to also address opportunities similar to those discussed in this paper. The speed of this evolution means that in 20 years from now, it is nigh on impossible to predict the technology that will be prevalent and widespread in mobile networks. This in itself presents a challenge that has to be acknowledged and reflected upon, to allow both industries to enter into business together for today and the foreseeable future.

The inherent differences in the product lifecycles in the mobile and automotive industries underline the importance of operators and automakers working closely together to ensure seamless services for consumers.

4.2. What are the first results from this cooperation?

Based on this premise, the GSMA's Connected Car Forum has been successful in:

- Bringing the primary actors to the table from multiple geographies, and
- Defining first user requirements and use case definition for services.

The focus of the first technical work has been on the:

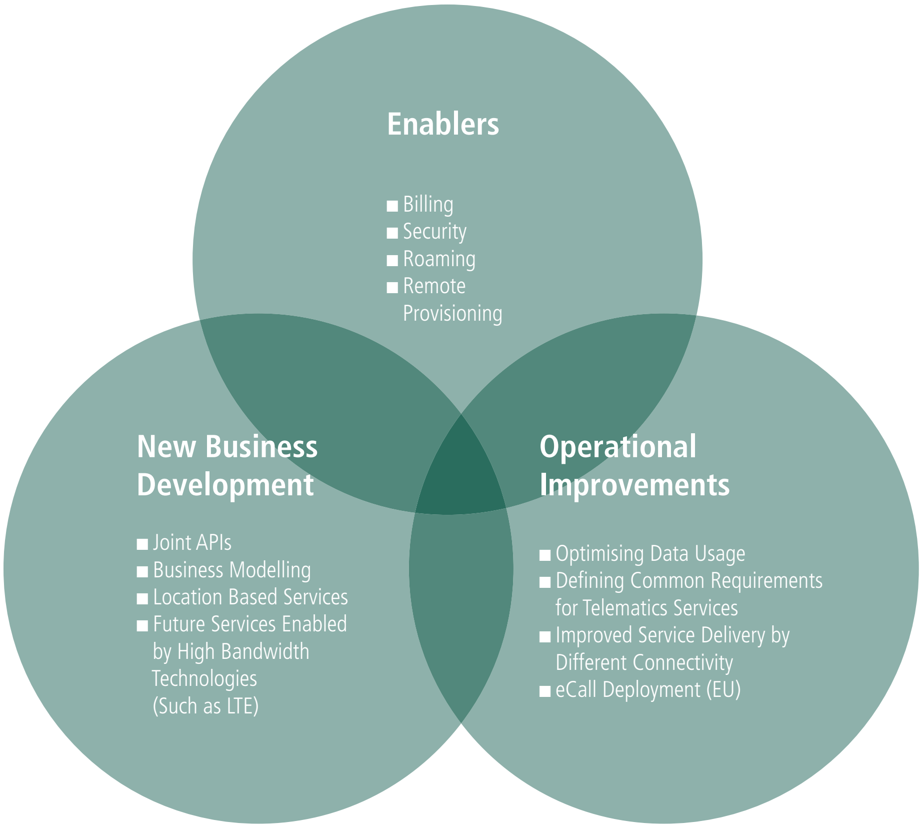
- Definition of the basic industrial and technological requirements for telematics and infotainment and services (for today and future evolutions);
- Identification of priority areas for cross-industry cooperation;
- Development of first stage requirements and use cases for remotely-provisioned SIMs in the automotive sector;
- Mapping of the primary obstacles in utilising different connectivity options, i.e. tethering and brought-in smart phone integration.

4.3. Where could cross-industry cooperation continue to be beneficial?

Based upon these discussions, further areas for potential cross-industry cooperation have been identified, generally classifiable into three categories:

- Advancing enablers which will unlock the full potential for connectivity support services in telematics and infotainment, including remote provisioning, billing, roaming, security;
- Ensuring operational improvements (such as improved service delivery by different connectivity methods (tethering and smart phone integration), eCall deployment, defining common requirements for telematics services and optimising data usage);
- Exploring the opportunities for fostering new business developments, including joint APIs and how to create and foster a scalable, viable and user-friendly application ecosystem.

Figure 31: Breadth of Potential Joint Cooperation Areas



Source: GSMA 2012

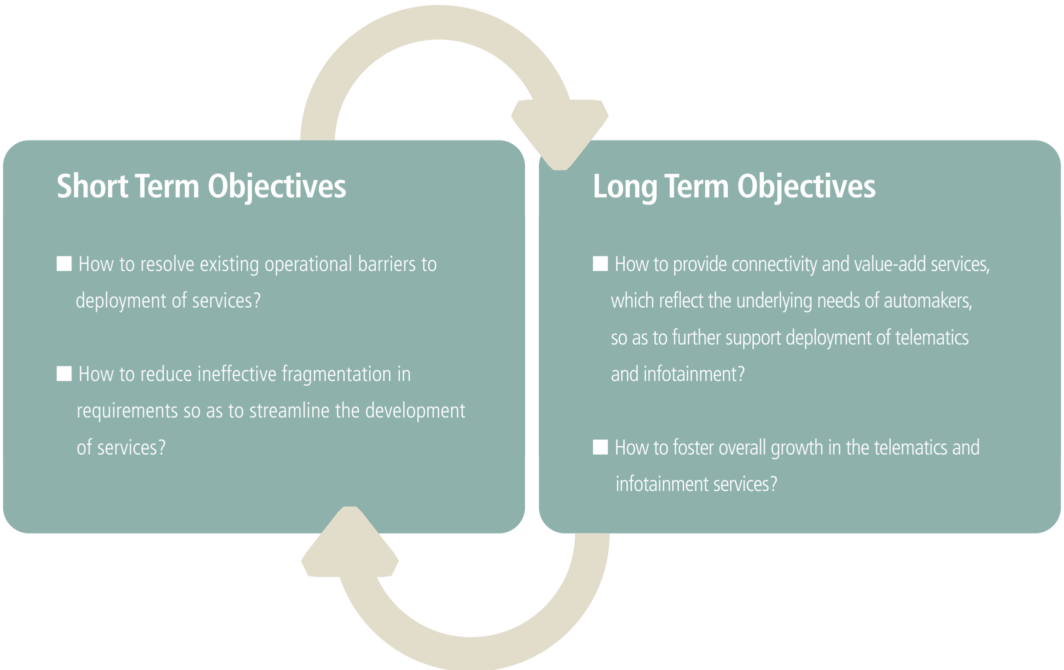
Ultimately, co-operation in these areas would drive:

- An increase in the overall market for telematics and infotainment;
- A reduction in the fragmentation in the market;
- The development of better operator solutions, which match automaker requirements and, therefore, ultimately result in an improved end user experience;
- Strategic business development.

These goals can be classified as:

- Shorter-term objectives, in which positive outcomes are likely,
- Longer-term objectives, which need to be addressed if the full potential of connected car services is to be reached.

Figure 32. Principle Means to Improve the Telematics and Infotainment Services through Cross-Industry Action



Source: GSMA 2012

4.4. Priority areas for cooperation between operators and automakers

Although a large number of potential areas of cooperation have been identified, we recommend immediate cooperation between operators and automakers in three areas:

- **Charging principles:** (in domestic and roaming scenarios) to support service-based billing and split billing;
- **Tethering:** provide operators with methods to allow tethering within automotive use cases.
- **Business interfaces:** for remotely provisioned SIMs (including possible automotive proof of concept).

Furthermore, at the European level, automakers and operators need to co-operate around deployment issues for eCall. This topic is critically important in order to ensure that the opportunity for increased car connectivity at the mass-market level is as successful as possible.

4.5.Who should be involved in these cross-industry activities?

Key global players in the primary geographies, Asia-Pacific, China, Europe, and North America, from both industries need to be actively engaged in co-operative initiatives to foster connected car services.

The involvement of other value-chain actors is a useful mechanism to handle specific thematic topics, particularly in those areas where both the barriers and opportunities involve a broad variety of players (beyond just automakers and operators), such as tethering.

5. Annex

Glossary

2G

Second-generation wireless telephone technology. Most second-generation cellular telecom networks use the GSM standard.

3G

Third generation mobile telecommunications - a generation of standards for mobile phones and mobile telecommunication services fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specifications set out by the International Telecommunication Union - the specialized agency of the United Nations which is responsible for information and communication technologies.

4G

4G is the fourth generation of cellular wireless standards, providing broadband mobile communications that will supersede the third generation (3G).

APIs

Application programming interfaces are source code-based specifications intended to be used as an interface by software components to communicate with each other.

App store

The purpose of an app store is to allow users to browse and download applications to an in-car system. Applications are likely to be controlled by the vehicle manufacturer to ensure a consistent HMI and to ensure only 'safe' driving apps can be used.

bCall

Breakdown call – a service which will send the current position of a broken-down vehicle to a roadside assistance organisation and initiate a voice call.

Embedded system

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is specifically-designed for a particular function.

ETSI

The European Telecommunications Standards Institute is an independent, non-profit, standardization organization.

Fleet management

A service, which permits the owner or manager of a vehicle fleet to monitor the status of the vehicles remotely.

GSM – Global System for Mobile Communications

A standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (2G) digital cellular networks.

HLR - home location register

The mobile operator's system for the storage and administration of individual user subscriptions on the mobile network.

HMI – human machine interaction

The space where interaction between humans and machines occurs.

HSPA – High Speed Packet Access

An amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), which extend and improve the performance of existing WCDMA protocols.

IMSI - International Mobile Subscriber Identity

A unique identification associated with all GSM and UMTS network mobile phone users.

LTE – Long Term Evolution

A standard for the wireless communication of high-speed data for mobile phones and data terminals.

MNO – Mobile Network Operator

A telephone company that owns and runs a network that provides services to mobile phone subscribers.

MNVO – Mobile Network Virtual Operator

A mobile phone operator that provides services directly to their own customers but does not own key network assets, such as a licensed frequency allocation of radio spectrum and the cell tower infrastructure. Instead these assets are leased from a mobile network operator in the region where the MVNO operates.

OEM – Original Equipment Manufacturer

In the context of this document OEM refers to automakers.

OTA – Over-the-Air

Another phrase for wireless communication, this is the transfer of information between two or more points that are not physically connected.

Remote management

This monitoring service enables vehicle status information to be sent to a remote end user. Examples of this information can include vehicle position, fuel level, or alarm notification status.

SIM – Subscriber Identity Module

An integrated circuit that securely stores the International Mobile Subscriber Identity (IMSI) and the related key used to identify and authenticate subscribers on mobile telephony networks.

SM - Subscription Manager

A new role in the provisioning ecosystem to manage the relationship between mobile operators and embedded SIMs. Its key responsibilities are the generation of operator profiles in real-time, management and execution of operator policy control functions and secure routing of profiles from operator personalisation to embedded SIMs. Note - the final definition of a 'subscription manager' is still being defined by the GSMA Embedded SIM project.

SVT – Stolen Vehicle Tracking

A system, which facilitates the recovery of a vehicle after theft.

TCU – Telematics Control Unit

The embedded vehicle control unit that communicates with the automobile's controls, GPS satellite and customer service centre to provide telematics features to a driver.

UICC – Universal Integrated Circuit Card

The smart card used in mobile terminals in GSM and UMTS networks. The UICC ensures the integrity and security of all kinds of personal data, and it typically holds a few hundred kilobytes of data.

UMTS – Universal Mobile Telecoms System

A third generation mobile cellular technology for networks based on the GSM standard.

Cellular Network Technology: Additional Details

Primary operator principles

Redundancy, resilience and availability

Telecoms networks work to a principle referred to widely in the industry as 'five 9's' availability. This means that the network should be functioning 99.999% of the time, or put another way, the network can only be unavailable for an average of 5 minutes and 15 seconds per year.

Mobile operators aspire to this metric, but it is a challenging target to reach, particularly in a network where a radio interface provides the connectivity to the customer. The geographic coverage of the different mobile technologies in mobile networks today varies considerably according to the extent of the roll out of each technology and the spectrum available for each technology.

In the 'wired' parts of the mobile network, operators implement redundancy in three key ways, to protect the customer from any effects resulting from different types of failure. These are:

- **Link redundancy**: this means that various elements within the network are connected by pairs of connections (be that wires, fibres, point-to-point radio connections or a combination of these). This means that if one of the connections between two pieces of equipment fails for some reason, the second connection is able to automatically pick up the traffic without the calls or session being disrupted.
- **Node redundancy:** this implies that critical functions are either paired (1+1 redundancy) or if the function is clustered so that more than one of the same element is on a site, there is a 'stand by'element (N+1 redundancy). This means that should one node fail completely, there is another equivalent node on 'warm stand by' that can take over any calls or sessions that would otherwise be lost. More advanced mechanisms for this are referred to as 'pooling', where multiple elements of the same type appear to the rest of the network as one large element, and so any individual failure is completely hidden from the network operationally.
- **Component redundancy:** within each node there may be, for example, ten cards that are all performing the same function. The node would be configured to have nine of those cards live and the tenth as a hot stand by ready to take over should a component fail on one of the other cards.

If any of the above failures take place, the redundancy mechanisms that are implemented will mean that the network does not fail and/or calls are not lost. Any such failure also triggers alarms in the network operation centre (NOC) which can then be addressed by maintenance staff who can replace any failed parts or re-establish connectivity.

More fundamental failures, such as power outages, are mitigated against through the implementation of batteries, diesel generators or some other form of site-based power supply.

The result is a network that is highly resilient to failure of equipment and connections, and hence offers a high-availability service to its customers.

As mentioned earlier, the resilience and robustness of a network does not imply that coverage using any specific radio technology is assured (the topic of radio technology and its relationship to coverage is addressed elsewhere in the document), but the availability of the network when a device is connected to it is very high.

Authentication and Security

Every mobile customer is familiar with the experience of turning on their mobile phone and being assured that the network recognises them and will route calls made to their phone number correctly. To do this, the network and the device have to establish a "trust relationship" that can be relied upon. This is done by using encryption algorithms and network-generated 'challenges' to the customer's phone to make sure the network can be sure that the phone (and more importantly, the phone number and associated subscription) is who it says it is and is entitled to service.

Two elements are involved in this trust relationship. One is in the device and is often referred to as the ‘SIM card’ – it is in fact more correctly called a UICC (Universal Integrated Circuit Card), which has a SIM application installed on it. The UICC has proven itself to be a remarkably secure and resilient platform on which to host security-sensitive applications and services. The UICC is widely used, not just in telecoms, but also in banking (the same technology is implemented on “chip and PIN” credit and debit cards) and other applications because of its high level of security and its suitability to host and support sensitive applications and services.

The SIM application on the UICC uses security credentials to generate responses to challenges generated from the network by the second element in the trust relationship, the authentication centre (AuC). The AuC, which is a core network infrastructure element, holds security profiles for every subscriber to the mobile network. When a device needs to be authenticated, the AuC generates security parameters that are used in the challenge to the SIM application on the UICC in the customer’s device. It also generates the expected result from the SIM application which is then compared with the result that is returned from the SIM itself.

When there is a match, the subscriber is considered to be authenticated to the network, or confirmed to be who they claim to be and they have a valid subscription to obtain service. On the basis of this authentication, calls to the phone number associated with the authenticated subscription can be routed to the customer and activity for which the customer will be billed can be correctly recorded and charged to that account.

When considering this in the light of requirements for embedded mobile services, it remains fundamentally important that a device and subscription is unique and is authenticated to the network to prevent fraudulent behaviour, as is the case with GSM and mobile technologies evolved from GSM’s security architecture. This ability to uniquely identify and authenticate users is fundamental to correct billing for service (see next section) and also is key for any location-tracking services.

Once an individual has been authenticated, it is important to also secure traffic that is generated and passed across the network. Mobile networks are built to a high level of security integrity, and successful attacks on mobile networks are extremely rare. Attacks can come in the form of electronic or viral attacks, or in the form of physical damage to equipment and installations, but these are exceptionally rare. In either case, networks are designed to withstand and repel such attacks with minimal or no impact on the service being provided.

The air interface between device and network is possibly the most vulnerable part of the network. But even here, the use of encryption algorithms, and the complexity of the air interface used to protect traffic over the radio interface, make cryptographic attacks impossible to achieve in real time and are, otherwise, extremely difficult to execute. In order to attempt to hack the air interface, a prolonged period of transmission and collection of encrypted traffic is required to allow for interception and decryption to occur, but this occurs very rarely. Although it is theoretically-possible to launch an attack involving the insertion of an unlawful interception tool in the air interface, an attacker would need to first identify the intended target, which is made difficult by virtue of the use of temporary identities to protect the anonymity of mobile users. Moreover, the attack would require a prolonged period of connection, in which the target doesn’t move to a new cell, which is contrary to the whole purpose and nature of services that are designed to enable mobility. Attackers would also need to have significant technical skills and resources, beyond the capabilities of the vast majority of the population. These three things make any such attack most unlikely to succeed.

The one point of vulnerability in relation to a service over a mobile network is the service itself. The growth of smartphone usage and the attachment of laptops to mobile networks has highlighted that, no matter how secure you make a network, you cannot protect customers from themselves. As with personal computers, downloading applications and content from untrusted third party sites can result in viruses being downloaded unbeknownst to the customer. Poorly implemented applications can also been prone to attack from hackers. Although industrial applications can place faith in the mobile network’s integrity to assure protection at one level, they also need to ensure that their service suite, passing over the mobile network, is equally secure, for the sake of their customers.

Billing

Billing systems go hand-in-hand with the authentication and security mechanisms of the mobile operator network. If a customer cannot be correctly identified, or the traffic that they generate cannot be allocated and recorded correctly, it is impossible for the network to generate an accurate, event-based bill. Currently, billing systems (BSS) are designed to identify specific events for which charges are levied against the customer's account – these are referred to as 'billable events'. The network watches the traffic that is generated by a customer and monitors for these billable events. When events occur, they are reported from the network to the BSS in call data records (CDRs). The CDRs are then correlated in the BSS and result in either charges being added to the customer's bill, if they are a post-paid customer, or credit being deducted from a customer's pre-paid account if they are a pre-paid customer.

By using the mobile operator's billing systems to generate charges and to understand connection utilisation by individual devices, third parties can in turn pass on charges (if the use case for such a service is designed around that model) or be assured that the charges being levied by the mobile operator to a third party are accurate. The integrity that has been built into mobile operator billing systems can be used by businesses outside of the traditional mobile telecoms value chain to understand a great deal about their customers' usage patterns.

Equally, operator billing systems can be used to manage other forms of contract that may be required by different sets of their customers. Wholesale agreements with companies or enterprises can be facilitated to provide a single bill for a large number of individual devices, even when those devices may not be tied to an individual person. This makes the operator capable of providing bills to customers with large numbers of 'non-traditional' devices as a consolidated bill. Operators can support any form of charging model, from a flat rate monthly service charge to a highly granular bill, with detail of each individual occasion of device-network interaction. No change in network technology is required to enable this, only an understanding of the contract and suitable software changes to reflect the billing model on the customer bill itself.

Subscription and device management

The mobile operator has a responsibility to manage its customers' subscriptions correctly, so that the customer receives all services that they are entitled to and equally does not receive (and as a result, is not charged) for services that they do not subscribe to. The management of the subscription for an individual customer requires technical integration between customer care systems, provisioning systems and the subscription management elements within the mobile operator network, these being the home location register (HLR) or home subscription server (HSS).

Customer care and customer support

Mobile operators have a commitment to support their customers that is not typical in other related sectors, such as internet or computing sectors. This has traditionally been done via call centres, but is increasingly moving to online support as a cheaper, more efficient option. The expertise that mobile operators have in being able to provide end users and corporate customers with advice and support on matters relating to both their services and the devices in the hands of the customers has considerable value which can be extended to include support for services that are in the embedded mobile sphere.

Operators often support large corporate clients with dedicated customer support teams, and so for a deployment of a large number of embedded mobile devices, operators could similarly provide a customer support offering which is tailored to the specific requirements of the organisation operating those devices.

Network characteristics

Coverage

2G GSM service is supported in every country on the planet by at least one operator per country, and in most cases, more than one. Coverage levels are high due to the use of low frequency spectrum bands and because the roll out of GSM networks has been taking place for more than 20 years. In many markets, population coverage is close to 100%, whilst in all markets, population coverage is high paving the way for widespread adoption of GSM and the ecosystem of technologies that followed it.

Coverage for EDGE is a subset of that for GSM and GPRS. Some networks have not deployed EDGE at all, whilst others have deployed the technology in areas where 3G coverage is difficult - 3G licensed spectrum is often in higher frequency ranges limiting the range of each base station.

3G is available in many countries, but there remain some nations where the government has yet to license 3G spectrum. Where 3G networks are available, coverage tends to be a subset of that of 2G, partly because the cost of deploying widespread 3G networks can be high - in many cases 3G is deployed in 1800MHz spectrum bands or higher. To achieve the equivalent coverage, this spectrum range requires 5 to 10 times the number of cells required in the 900MHz band (which is widely used for 2G). This in turn means that even in countries where 3G spectrum has been available for some time, 3G coverage may be limited to urban and suburban areas, and perhaps along major transport links such as roads and train lines. 3G coverage may well be limited in rural areas.

Because HSPA and HSPA+ exist in the same spectrum as UMTS (in fact they are an evolution of UMTS) they are subject to the same coverage constraints. However, mobile operators are likely to continue to invest in HSPA coverage either to provide a full broadband network or as a complementary technology to their LTE deployments. The motivation to deploy increased HSPA coverage is far greater than that for UMTS, since the service experience is better for the consumer and has been widely embraced.

LTE coverage today is low, both in terms of the number of markets that have live LTE network deployments, and in terms of the LTE coverage offered within those markets by the operators that have launched. The timing of LTE deployments depends in part on the availability of 'digital dividend' spectrum (discussed further below), which is in low frequency bands, and hence is suitable for good rural coverage. However, LTE at the moment is still in its infancy and so network build-out is slow and relatively expensive. Over time, LTE deployment is likely to follow the same pattern as 2G and HSPA service roll out, with growing adoption creating economies of scale for suppliers of network equipment and device components, driven by increasing scale and adoption. As LTE scale grows, costs fall, making the service more accessible to more of the customer base, which in turn drives further adoption, and hence, greater coverage on more networks.

Bandwidth

Bandwidth on GSM and GPRS is very limited. As the technology for GSM networks was originally optimised for carrying voice transmitted using a narrowband codec with limited radio resources, using GSM to support high bandwidth data services is not feasible.

EDGE networks support a range of peak bandwidths from 238kbps to 2.048Mbps (if EDGE Evolution is used, although this has only recently been deployed). These are theoretical maximums and the achievable real throughput is generally between 2/5 and 1/5 of this bandwidth.

The first 3G networks had a peak throughput of 384kbps. In practice, data transmission rates were considerably slower than that. HSPA began with theoretical maximum supported data rates of 1.8Mbps or 3.6Mbps. However, HSPA networks and devices now support peak rates of 7.2Mbps, 14.4Mbps, and HSPA+ peak rates of 21Mbps, 28Mbps and 42Mbps. There are plans to support at least 84Mbps in the future, and standards work has begun to allow for eight bearers to be bonded together giving a maximum throughput of 672Mbps. However, it is questionable whether any operator would hold sufficient spectrum for this maximum rate to be achieve. Real throughput tends to average between 1/5 and 1/7 of theoretical maximums. This still makes HSPA+ bandwidths as good as, or better than, most ADSL services.

LTE has theoretical peak download rates of 170Mbps, and early network deployments are delivering data rates between 10Mbps and 50Mbps. These rates are generally in excess of those available on current consumer fixed line services using DSL and cable modem technologies.

Latency

GSM is optimised for the delivery of voice calls, so latency is low on the radio interface. Similarly, EDGE latency is low – around 150ms. Since EDGE, in part, makes use of TDM signalling, but with much higher bandwidth data channels, the latency of a voice call being carried on EDGE can be very low indeed. However, since latency on 2G networks is low in general anyway, the improvements provided through deployment of EDGE are not usually perceptible to customers on voice calls.

3G networks have fairly low latency characteristics – the use of 3G networks to support voice calls is fairly widespread. The shift from TDM to CDMA as a radio multiplexing technique enables support of greater data rates, but does result in a small increase in latency. Since HSPA offers a major increase in bandwidth, latency on voice calls is relatively low.

Low latency has been designed into LTE from the outset. A radio latency of less than 10ms is the requirement, which makes LTE an ideal technology for voice services and video telephony. It should be noted that the Voice over LTE standard uses a different mechanism to previous radio technologies – instead of using circuit-switched technology for voice, Voice over LTE specifies that voice calls are delivered via a technology called IMS, with the service definition having been completed by GSMA.

Limiting factors – some things we can do nothing about

As good as a mobile operator’s service may become, there are some aspects of mobile technology that are outside of anyone’s control. These mostly relate to limitations due to the laws of physics.

Mobile technologies use radio waves, and whilst radio waves do penetrate into buildings, the level of penetration and hence the coverage and data rate achievable decreases as frequency increases. This is not a major concern for the automotive industry since the nature of vehicles is to be outdoors when in use, but it does mean that coverage in tunnels is likely to be poor.

Equally, placement of the antenna on a vehicle will be a critical factor to the service received by the customer. An antenna that is placed inside the vehicle (which would perhaps be the case when considering tethering of a handset) will be much lower than that for an antenna on the exterior of the vehicle. This is because vehicles are, by design, moving metal boxes, and metal boxes reflect radio waves, thus meaning the coverage in a vehicle is affected adversely.

Coverage can also be affected by radio interference from other sources of radio waves in the local environment. This can include many other types of electrical equipment, overhead power cables and fluorescent lights. In most cases, such sources of interference do not remain persistently close to a moving vehicle, but it is worth considering that affects can be found in localised areas.

Why is spectrum so important?

Spectrum for GSM/GPRS has been identified and licensed around the world for a number of years, with a fairly high degree of alignment in the spectrum bands used. This in turn means that chipsets for 2G technology are very cheap compared with more recent technologies, to the extent that 2G handsets can be priced at under $30 in some markets. This spectrum is ring-fenced, to some degree, due to the importance of 2G networks to the world’s communication capability and the world’s economy. Re-farming of 2G spectrum (particularly in the 850MHz and 900MHz bands) has been discussed, but hasn’t gained significant momentum. This is due in part to the logistical issues of clearing the band of customers, particularly in a market where new embedded mobile services in other business sectors are making new use of 2G technology (for example smart metering and utility network management and monitoring). Operators that see decreasing 2G penetration in their own customer base may still want to support 2G in-bound roamers. As a result, some level of 2G network support will likely continue to exist for some time to come in many markets. EDGE is deployed in 2G spectrum with GPRS and GSM. Compatibility between the technologies exists so EDGE can be deployed into any spectrum band allocated for 2G.

3G spectrum bands have been licensed for some time in many developed markets, but there remain markets that are without 3G licensed spectrum today. However, the licenses that have been issued tend to be well-aligned internationally making global 3G chipsets fairly cheap. 3G spectrum can be used for UMTS, HSPA and HSPA+.

LTE cannot exist in the same specific license spectrum band as pre-existing technologies, which implies that new spectrum licenses are needed in many cases. The two primary spectrum bands for LTE are the ‘digital dividend’ at 700MHz or 800MHz (dependent upon market) and 2.6GHz. Digital dividend spectrum is being freed by the move from analogue to digital broadcast signals for television. Since the analogue to digital switchover is an on-going process in many markets around the world, the timing of the availability of this band varies across markets. 2.6GHz spectrum is open in most markets and so has a good degree of alignment in licensing internationally. This spectrum is also being licensed around the world at the moment with varying timelines.

There is also a TDD (Time Division Duplex) variant of LTE, which is being deployed in 2.3GHz spectrum (sometimes referred to as BWA spectrum). TD-LTE is likely to be adopted in China and India, and as a result will have significant scale globally, making TD-LTE attractive to many other operators in other markets. Chipset manufacturers are producing TDD- and FDD-capable chipsets and so it is likely that the distinction between TDD and FDD will not be apparent to the consumer (and the device).

There is also considerable interest in the deployment of LTE in the 1.8GHz band. This spectrum has been licensed for some time in many markets, but has not always been utilised. Studies are on-going about the usage of 1.8GHz bands for LTE with a view to encouraging a global ecosystem in this band to support LTE deployments.

There is a growing trend among a large number of regulatory regimes towards ‘technology-agnostic’ licenses. It is this trend that allows for previously licensed, but unused, 1800MHz spectrum to be considered for LTE. It will also be this shift that may usher in the potential for re-farming of spectrum to be used for different mobile technologies than those it was originally licensed for.

As bandwidth demands increase due to rising usage of dongles and smartphones, operators may consider re-farming their existing spectrum bands to higher bandwidth technologies. Re-farming has the potential to:

- address the overall bandwidth requirements of customers in the future, and also
- provide a potential mechanism to use lower frequency bands (which result in higher coverage levels due to larger cell sizes) to deliver much greater bandwidth capacities in rural areas than today.

The decision about which bands to re-farm is not straightforward since any customers that are currently dependent upon the band that is being re-farmed will be affected. Some existing mobile services have been sold on the basis of the high coverage levels of 2G, whilst others are based on the higher bandwidths of 3G technologies. The decision is also likely to be influenced by the individual regulatory environments in each country and the conditions of the original license.

Making an existing license technology-neutral does not automatically trigger the end of an existing service and a shift to something new, but it certainly removes a barrier to that occurring. In most markets, issued licenses have been used to deploy technologies and customers are dependent on those services. It is, therefore, a significant technical, commercial and regulatory task to administer the re-farming of any spectrum band.

Network generation details

2G – GSM and GPRS

GSM was the first digital mobile technology to be defined and has become the de facto choice of technology for around 800 mobile operators today. It was originally defined to support voice calls using Time Division Multiplexing (TDM). TDM is optimised for voice transport, since it is low latency, but it is not good for delivery of large amounts of data. As a result, when GSM was extended to also include a 'packet switched' or data delivery network (also known as GPRS), the maximum theoretical throughput was only 40kbps, with actual network speeds mostly below this. These speeds were achieved through the aggregation of multiple time slots of GSM signal into a single data stream.

In addition to supporting voice, GSM also provided the capability to deliver the Short Messaging Service (SMS). SMS was originally intended to be a basic M2M mechanism for sending short commands to devices attached to the mobile network. The expansion of SMS into a person-to-person message service happened after it had been defined and was actually not its original application.

2.5G – EDGE

Whilst EDGE (Enhanced Data rates for GSM Evolution) is widely referred to as '2.5G' it is, in reality, an accepted technology in the ITU-R IMT-2000 family of technologies and so could strictly be called a 3G technology. EDGE came about through the move to a more efficient encoding technique on 2G radio data paths, which led initially to a maximum throughput of around 120kbps. However, further advancements in 3GPP have led to rates of 440kbps, and latterly, in excess of 1Mbps being theoretically possible. The adoption of EDGE has been relatively slow, as it was became available around the same time as 3G (UMTS) came to market, and many operators preferred to base their data connectivity strategy on the newer technology (particularly those that had spent a large amount of money acquiring spectrum for 3G roll out). However, today many networks support EDGE, although not always with the same degree of geographical coverage as GSM/GPRS is supported.

3G – UMTS

Whilst 2G networks had been designed to support voice and had then had data added on, 3G networks are designed and built with data in mind. 3G was developed as a part of 3GPP Release 99, and deployed widely from 2001 onwards. 3G was sold on headline rates of 384kbps, but in reality delivered much lower rates and as a result was not a huge consumer success on the basis of its own capabilities. This in combination with a number of teething problems associated with 3G <-> 2G handovers meant that initial consumer experience was poor, and 3G networks ended up being used primarily for voice, rather than data, traffic. It was not until the advent of HSPA (see following section) that mobile data services began to really take off. The other issue that slowed 3G adoption initially was the limited scope of Internet capabilities that were available through WAP services. WAP was intended to be a lightweight protocol for displaying internet content on mobile devices, but again, it would not be until the rise of the smartphone that a true web browsing experience equivalent to a fixed broadband connection would be realised.

For all of this, 3G networks are now widely adopted, but most 3G networks have now been transformed into HSPA networks, and thus the baseline UMTS 3G network is greatly improved.

3.5G – HSPA and HSPA+

Having seen the hype of 3G technology fail to be realised when practical implementation took place, it was perhaps unsurprising that HSPA's early marketing was relatively low key. HSPA was defined first in 2005 and launched shortly afterwards, but through aggressive pricing and the advent of the USB dongle, it soon became a significant success. The growth in adoption of HSPA was further catalysed by the advent of the smartphone. Smartphones depend on high bandwidth connectivity to make the consumer experience of the applications supported on the handset as good as possible.

With the addition of support for e-mail, social networking applications and a swathe of other ways for smartphones to enable the customer to 'stay connected' or to view content (including videos) whilst on the move, the demand for bandwidth on a network is increasing across three metrics – more customers are viewing more bandwidth intensive content for longer. This presents both a challenge to the network operator to support this rapidly escalating demand, but also an opportunity to find new revenue streams in the bandwidth-hungry market. Operators and equipment manufacturers are continually advancing the bandwidth capabilities that are offered to customers. The advancement from HSPA to HSPA+ through the use of QAM64 modulation, multi-carrier bonding and MIMO technologies means that HSPA supports bandwidths up to 42Mbps in networks today and has potential to go far beyond that, even to speeds in excess of 600Mbps in its most extreme incarnation.

As at December 2011, HSPA had 600 million worldwide connections and the growth in HSPA connections (currently running at around 19 million per month) shows no sign of slowing. In October 2012, it was reported by the GSA (the global mobile equipment supplier organisation) that all UMTS networks also support HSPA in at least part of their network, and most operators with newly-licensed 3G spectrum move directly to HSPA as their first deployed technology.

LTE – is it 4G?

LTE is being marketed by many operators around the world as '4G', but this is not strictly true. LTE is in fact an IMT-2000 technology and hence comes under the 3G categorisation with UMTS, HSPA, HSPA+ and other technologies mentioned previously. The IMT-Advanced process to define '4G' technologies has recently concluded with LTE-Advanced and WiMAX2 identified as 4G technologies. For all of this, many mobile operators have announced that LTE is '4G' and so the marketing machine has started an irreversible branding of LTE.

LTE is likely to impact the mobile industry in two major ways. First, it is set to deliver practical data rates that are in excess of 20Mbps, and early signs are that it can deliver this throughput. TeliaSonera launched the first commercial LTE network in Sweden at the end of 2009 and has reported average rates of 25Mbps and peak rates in excess of 50Mbps. Second, and perhaps most importantly, LTE is expected to be a technology that will be implemented by operators across the world.

Five years ago, LTE was often compared with WiMAX, with proponents of WiMAX claiming an advantage in terms of time to market. Since then it has become clear that WiMAX will play little more than a niche role in the industry – most mobile operators have made commitments to LTE as their future technology, and some operators that have initially deployed WiMAX are now switching to LTE. Overall, WiMAX has attracted around 20 million connections globally in four years[17] and is on a slow growth trajectory. In the next two to three years, LTE will become a major technology in the industry with UMTS and CDMA operators both moving towards LTE as a common end goal.

17 This estimate includes implementations to provide fixed wireless access and incompatible WiMAX-like implementations in certain markets.

Additional technologies outside of the GSM family

Alternative 2G technologies

Whilst the vast majority (around 85%) of the world's operators use GSM as their 2G technology, other 2G technologies do exist. Some operators in North America and other regions employed a technology called RTT 1x, whilst operators in Japan chose to use PDC.

Alternative 2.5G technologies

Operators that had previously deployed RTT 1x often chose to move to CDMA 1x as a natural evolution path for their data networks. However, many operators that followed this path switched to the 3GPP-defined 3G standard in the next iteration of technology evolution (see following section).

Alternative 3G technologies

As with 2G, North American operators in some cases preferred to implement an alternative technology – CDMA-2000 EV-Do Rev0. This technology was also adopted by other operators in Korea, India, Australia, New Zealand and some other markets. However, in many cases, the operators in these additional markets have ended up deploying UMTS as well, most notably Telstra in Australia. It should be noted that operators that have received licenses for 3G technology in the past two to three years have tended to skip 3G, and move instead directly to 3.5G technology – see the next section.

Alternative 3.5G technologies

Operators using CDMA-2000 EV-Do Rev 0 can extend these networks in the same way as UMTS operators can extend to HSPA. The technologies available are Rev A and Rev B, which are roughly analogous to HSPA and HSPA+. As mentioned previously, some operators have swapped from the CDMA-2000 technology track to UMTS and HSPA.

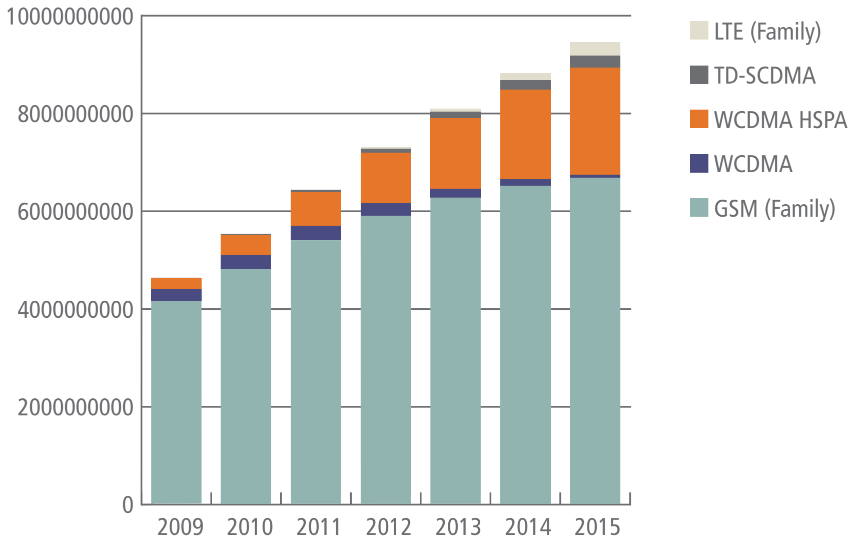
China Mobile, the world's largest operator by subscriber numbers, has deployed a further alternative technology – TD-SCDMA. Whereas all other 3G technologies mentioned previously use Frequency Division Duplex (FDD) on the radio interfaces, TD-SCDMA uses Time Division Duplex (TDD). This has meant that China Mobile's deployment is isolated from all others on the world telecom stage.

Regional deployment details

The following graphs depict forecasts by Wireless Intelligence (the GSMA's research arm) of network evolution to 2015 in terms of subscribers for different regional markets. For the different forecasts, it is important to note that:

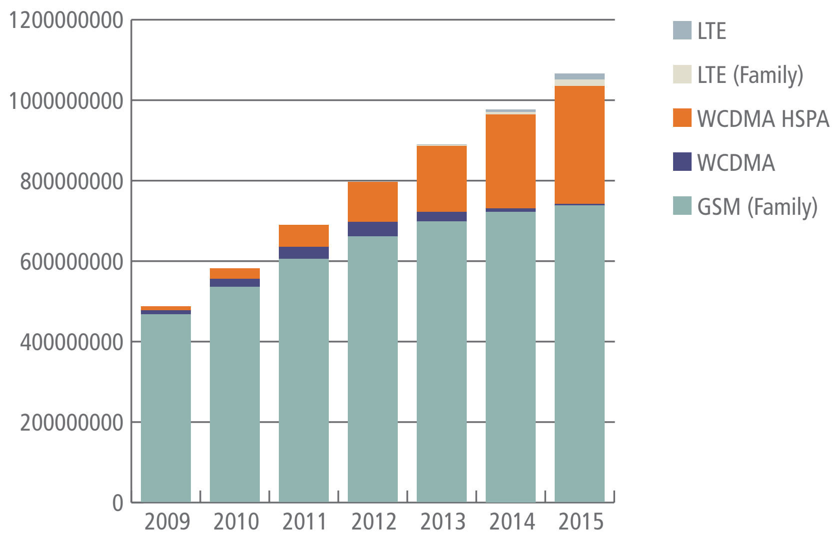
- LTE roll-outs are likely to focus on urban areas initially, and broader deployment will follow later; however some regulators have issued spectrum-licenses that stipulate nationwide roll-out of LTE[18]
- Spectrum re-farming will play an important role in the deployment of LTE, and other high-bandwidth network technologies
- GSM technology implementation remains strong at a global level
- Vanilla Wideband CDMA (WCDMA) subscriptions continue to rise only due to HSPA compatibility

World - Number of Network Subscribers



Source: GSMA Wireless Intelligence 2011

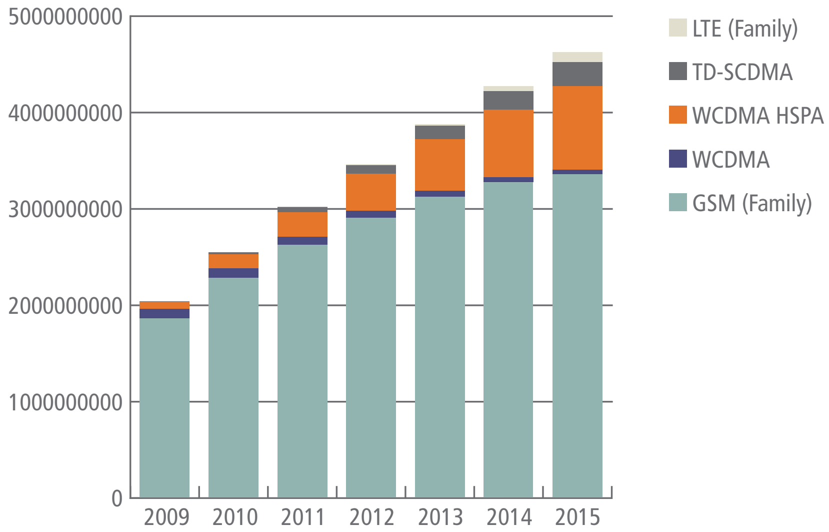
Americas (North, Central and South) - Number of Network Subscribers



Source: GSMA Wireless Intelligence 2011

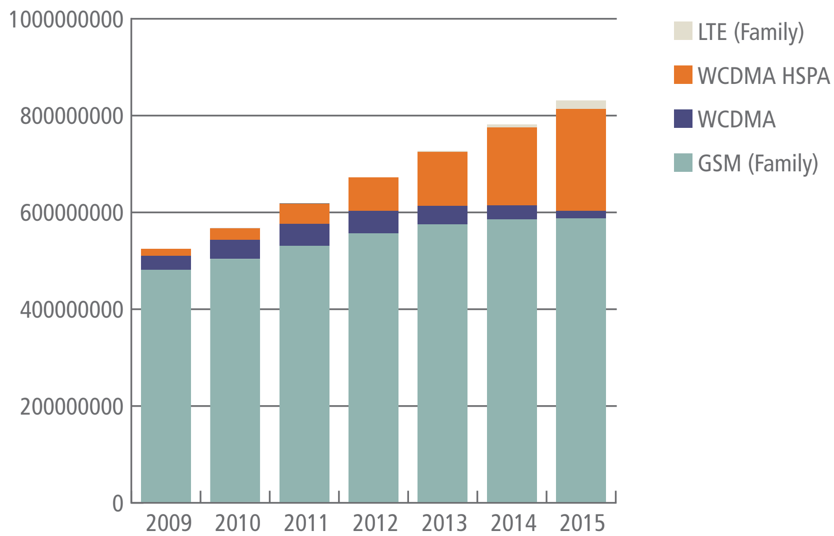
18 E.g., German operators that acquire spectrum in the 800MHz band will have to roll out mobile broadband networks in rural areas that have poor broadband access.

Asia Pacific - Number of Network Subscribers



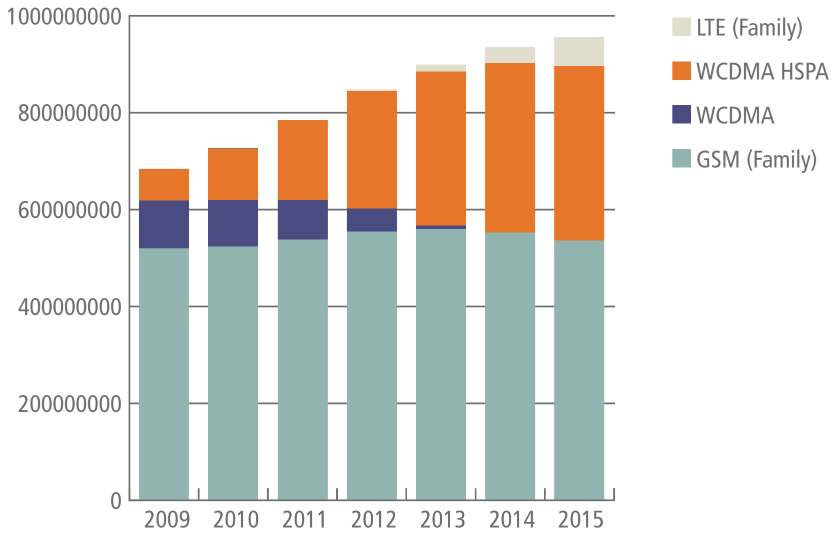
Source: GSMA Wireless Intelligence 2011

Eastern Europe - Number of Network Subscribers



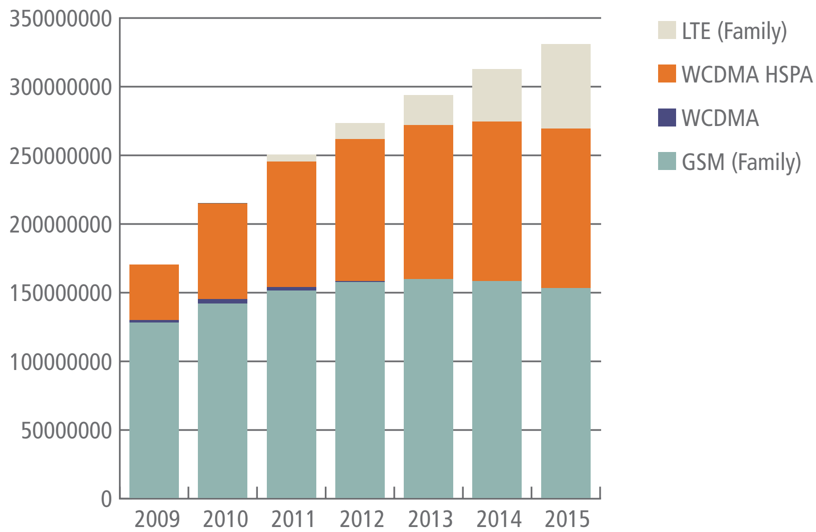
Source: GSMA Wireless Intelligence 2011

Western Europe - Number of Network Subscribers



Source: GSMA Wireless Intelligence 2011

US & Canada - Number of Network Subscribers

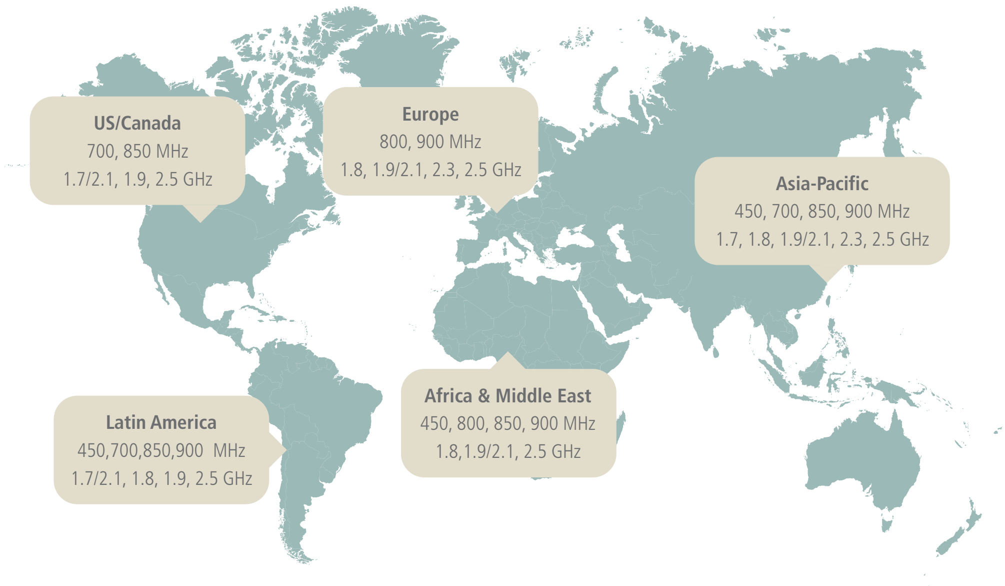


Source: GSMA Wireless Intelligence 2011

Regional Deployment Plans for LTE

Worldwide Spectrum Availability

There are multiple bands for LTE as defined by ITU - both paired and unpaired



Europe - Spectrum Bands for LTE

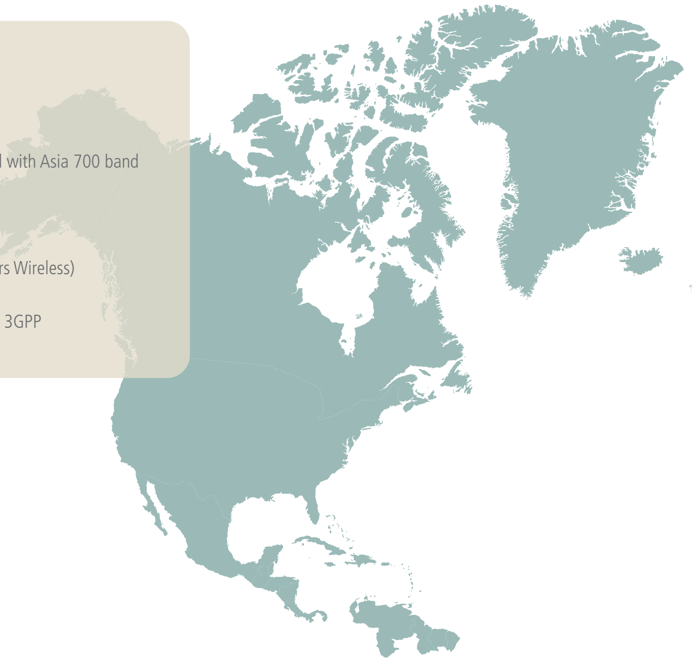
- 56 countries/terrotories
- 9+ bands
- Planned LTE bands
  - 700 MHz - not aligned with NA band
  - 800 MHz - European Digital Dividend band (Vodafone Germany, DT Germany)
  - 900 MHz - re-farming of existing GSM band
  - 1.8 GHz - operators considering reuse for LTE
  - 2.1 GHz - 3G band for possible reuse
  - 2.3 GHz - TDD band aligned across many markets
  - 2.5/2.6/2.7 GHz - aligned with many other markets (TeliaSonera)
  - 3.5 GHz - currently being defined for use in 3GPP

- Most operators in 1.8GHz, 2.6GHz or both
- Digital Dividend spectrum licensing in next 2-3 years

North America - Spectrum Bands for LTE

- 2 countries
- 7+ bands

- Planned LTE bands
  - 700 MHz - NA Digital Dividend, not aligned with Asia 700 band (Verizon wireless, At&T, MetroPCS)
  - 1.7 GHz
  - 2.0 GHz
  - 2.1 GHz - Reuse of existing 3G band (Rogers Wireless)
  - 2.5 GHz - aligned with Europe and Asia
  - 3.5 GHz - currently being defined for use in 3GPP



Asia Pacific - Most diverse spectrum bands

- 27 countries/territories
- 11+ bands

- Planned LTE bands
  - 700 MHz - but not aligned with North American band plan and some time away
  - 800 MHz - partly alighned with European band plan (SKT, LG U+)
  - 900 MHz - refarming of 2G spectrum - differing timelines globally
  - 1.5 GHz - specific to some markets in APAC, not used in other markets
  - 1.8 GHz - many operators considering reuse for LTE (SKT, HK CSL, M)
  - 2.1 GHz - 3G band for possible reuse (NTT DOCOMO, LG U+, SMART)
  - 2.3 GHz - TDD band aligned across many global markets
  - 2.5 GHz - alignment with many other markets (M1, CSL, HK)

Latin America - Spectrum bands

- 26 countries/territories
- 7+ bands

- Planned LTE bands
    - 700 MHz
    - 850 MHz
    - 900 MHz
    - 1.8 GHz
    - 1.9 GHz
    - 1.7/2.1 GHz
    - 2.5/2.6 GHz

India - Spectrum bands

- Band released
    - 900 MHz
    - 1800 MHz (2x35 MHz)
    - 2100 MHz (2x15 MHz)
    - 2.3 GHz (40 Mhz)
    - 2.5 GHz (20 MHz)
    - 1.7/2.1 GHz
    - 2.5/2.6 GHz

- Planned LTE bands
    - 700 MHz
    - 900 MHz
    - 2.3 GHz
    - 2.5/2.6 GHz

About GSMA

The GSMA represents the interests of mobile operators worldwide. Spanning more than 220 countries, we unite nearly 800 of the world's mobile operators, as well as more than 200 companies in the broader mobile ecosystem. The GSMA believes that the automotive industry has the opportunity to leverage existing mobile platforms and technology to provide innovative in-car services to a broad range of drivers through the provision of a consistent and standardized framework.

For the latest information on our mAutomotive programme please visit www.gsma.com.

About GSMA Connected Car Forum

GSMA Connected Car Forum, launched in 2011, enables automakers and operators to come together to reduce fragmentation and improve scale in in-car Apps development. Our current global priorities include defining specific requirements for remote management of operator credentials and use cases and business requirements for in-vehicle connectivity including both embedded solutions and tethered options. In Europe we are addressing eCall implementation issues.

To join the forum please email: mautomotive@gsm.org

Connected Living

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