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 deploy network technologies that support widespread, high-bandwidth connectivity and enable remote management of the SIM card.

The mobile industry is developing an embedded SIM, which can enable a swap between operators, without any need to have physical access to the mobile device. The standardisation of the remote management of SIMs is scheduled to be completed in 2013.

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). However, it is quite difficult to predict how LTE, in particular, will be deployed in any specific geography given that:

- Network evolution is driven by the commercial decisions of individual mobile operators, based upon the needs of their cumulative customer base
- LTE requires additional spectrum which will either need to be licensed, or for some operators, be re-farmed from existing mobile networks
- Spectrum is licensed at a national level.

The rapid evolution of mobile technology, such as smartphones, contrasts with the product development cycles in the automotive industry, which generally takes three to five years to develop new vehicles, which then have a typical lifespan of seven to 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 software 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 and integrated solutions (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 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, whilst also being as "future-proof" as possible 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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Introduction

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

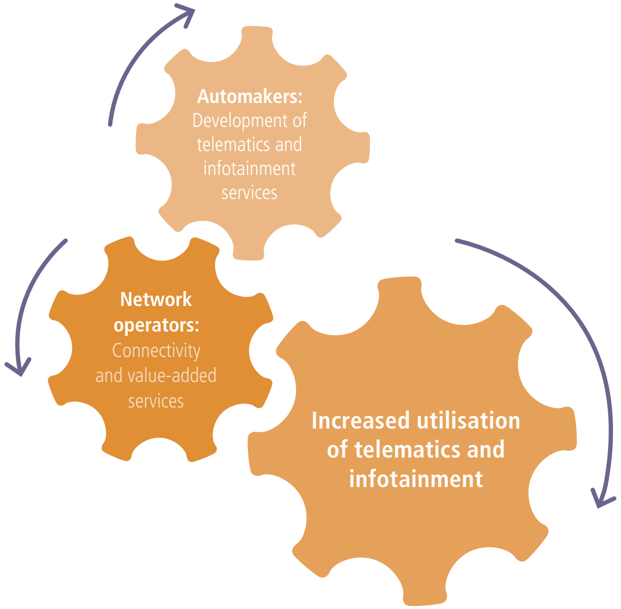


Figure 1: Automaker and Operator Interaction to Foster Telematics and Infotainment Services
Source: GSMA

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. This whitepaper 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 is based on the activities of the GSMA Connected Car Forum where global operators and automakers have met since June 2011 to cooperate to address mutual challenges. Participants in the forum include:

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

This white paper 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.

This whitepaper is also helpful for other value-chain actors, playing intermediary roles between mobile operators and automakers in the development of these services. Finally, this whitepaper 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 covers three key areas:

- **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 services.

This whitepaper's underlying premise is that only through cross-industry collaboration between automakers and mobile operators will it be possible to remove barriers to the safe delivery of connected services and applications in cars, as increasingly requested by drivers (see Figure 1).

Development challenges for cross-industry connected services

Figure 2 outlines the cooperation challenges between automakers and mobile operators:

Addressing the problem statement outlined in Figure 2 requires a meeting point between:

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

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

Historic cooperation difficulties across operators and automakers:

- Early telematics services often resulted in misunderstandings between MNOs and automakers
- Regulatory changes (in the EU) have slowed development in recent years.

Market structure:

- Market dominated by relatively few automakers wanting global solutions
- Fragmented market for 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
- Services are often not seamless, given fragmented connectivity approaches
- Driver distraction concerns impose specific, unique obligations on services for deployment
- Current business models have mostly been unable to directly cover the costs of providing services
- Security & privacy issues have a high profile as deployment of connected cars draws the attention of hackers
- Fear of roaming costs have reduced the utilisation of telematics services (switched off to avoid risks in border areas).

Market Evolution:

- Market demands are evolving, as more data-intensive services are set to be widely-deployed, requiring new technologies, business models and cooperation
- MNOs will need to meet these evolving requirements in order to maximise opportunities and become active players in the value chain (beyond connectivity).

Figure 2: Problem Statement between Automakers and Mobile Operators
Source: GSMA

Cellular Networks' Capabilities

This chapter reviews the basic characteristics of mobile network technologies and SIM cards, some of the key factors affecting their current deployment status, their future deployment and evolution. It 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 a fixed line 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 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 technology to other industries.

The 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 an 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)
- **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. These network criteria are important for the following reasons:

- **Coverage** – services that require continuous connectivity need near-ubiquitous network 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 reached nationwide coverage, newer technologies (that deliver broadband data rates) tend to have more limited reach

- **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 generally utilise newer modulation techniques 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 VoIP 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 this document, different use cases, based on these criteria, 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.

Figures provided in the following section on cellular network technologies are sourced from Wireless Intelligence – the research arm of the GSMA.

What are the key cellular network technologies?

In mobile telecoms, much is made of the generation of technology implemented by a network and supported on devices (see Figure 3).

- 2G GSM has broad global operator support and contributes to 70% of global mobile connections (as of Q3 2012). By contrast, 2G CDMA (1x) networks represent about 5% of the global connections market.
- 3G networks have brought data speed improvements from legacy 2G GPRS networks in which download speeds were limited to 140.8 kbps. The introduction of WCDMA networks doubled peak downlink speeds to 384 kbps, while upgrades to HSPA improved peak downlink speeds to 14 Mbps. Mobile internet services really began to gain momentum with the wider availability of WCDMA/HSPA networks which now account for close to 20% of global mobile connections (as of Q3 2012). By contrast, 3G CDMA (EV-DO) represents 4% of global connections, mostly in Northern America and East Asia.
- The 4G LTE market is still in its infancy with just over 100 commercial LTE networks now live, covering around 5% of the global population (in large cities mainly). Wireless Intelligence expects 4G LTE to represent 10% of global connections by 2017.

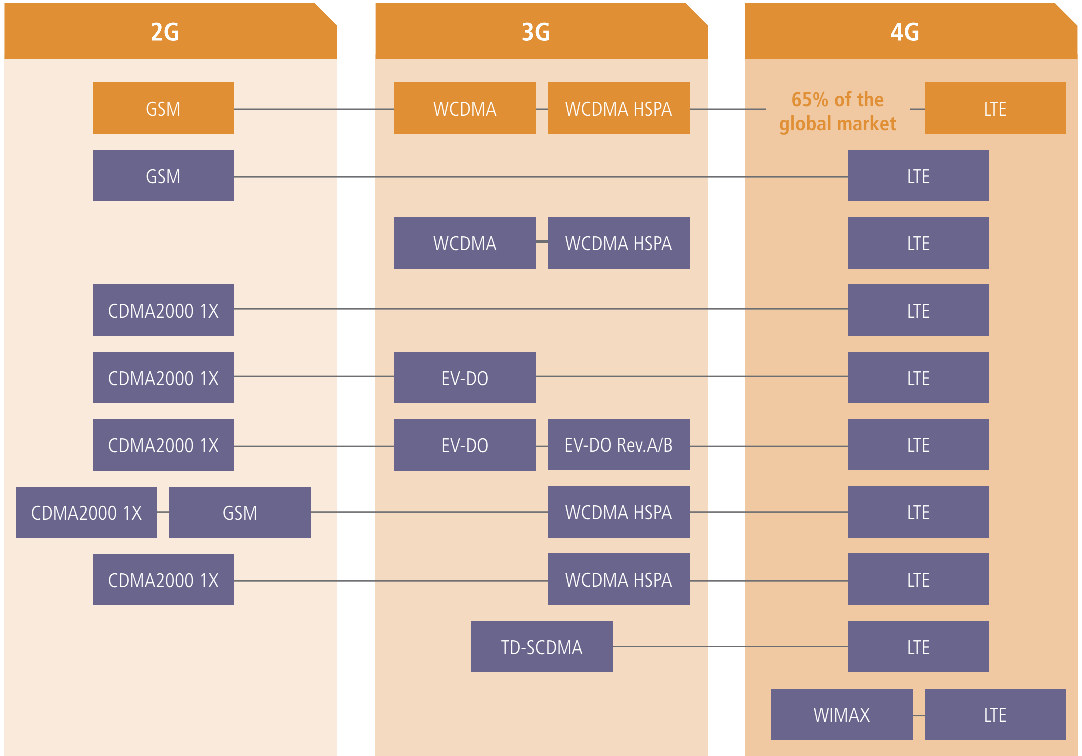


Figure 3: Typical Mobile Technology Migration Scenarios
Source: Wireless Intelligence

Cellular Network Generation		Maximum Downlink Data Rates	Latency	Current Coverage (1 Low – 5 High)
2G	GPRS	140.8 kbps	>500ms	★★★★★
	EDGE	473.6 kbps	150-200ms	★★★
3G	UMTS	384 kbps	200-250ms	★★★★
	HSPA	14.4 Mbps	50-100ms	★★★★
4G	HSPA+	42.2 Mbps	20-25ms	★★
	LTE	173 Mbps	5-10ms	★

Figure 4: Summary of the Characteristics of Different Network Technologies Based on Evolved GSM Core Networks
Source: GSMA

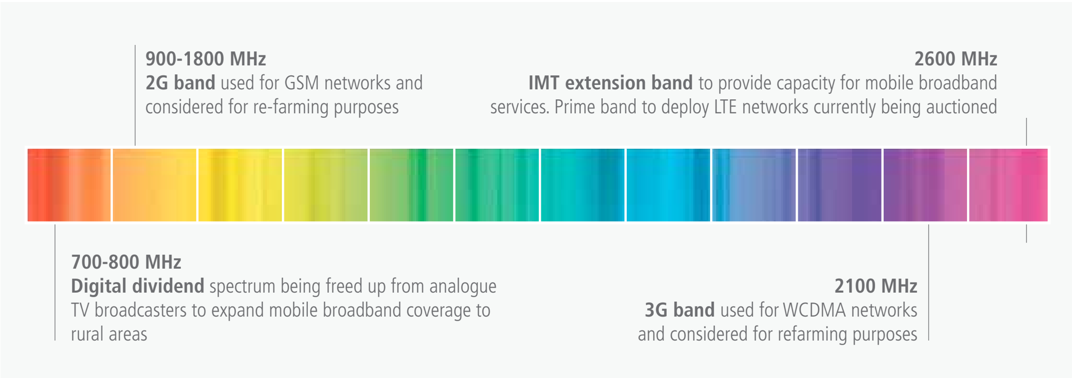


Figure 5: LTE Spectrum Landscape
Source: Wireless Intelligence

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 use, then the technology cannot be deployed in any given market. Secondly, the spectrum band in which a technology is used affects coverage and the cost of deployment. 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 2G GSM has been identified and licensed around the world, with a fairly high degree of alignment in the spectrum bands used, notably in the 900MHz and 1800MHz bands.
- 3G spectrum bands have been licensed for some time in both developed and developing countries, notably the 2100MHz band for WCDMA / HSPA. However, about 50 developing countries still do not have any commercial 3G networks (as of October 2012).[2]
- The deployment of the latest mobile technology, Long-Term Evolution (LTE), is dependent upon one of three scenarios: The allocation of IMT-extension spectrum (2500-2600MHz), the re-farming of existing 2G / 3G spectrum or the release of the 'digital dividend' spectrum (700-800MHz). A high level of spectrum fragmentation hinders LTE adoption, reducing the economies of scale available to LTE device makers. Six frequency bands (700 / 800 / 1800 / 2100 / 2500 / 2600MHz) dominate LTE deployments to date and there could be 38 different LTE spectrum combinations worldwide in LTE network deployments by 2015.[3]

The current LTE spectrum landscape is shown in Figures 5 and 6.

2 **Source:** Wireless Intelligence.

3 **Source:** Wireless Intelligence, Global LTE network forecasts and assumptions – one year on, published in December 2011.

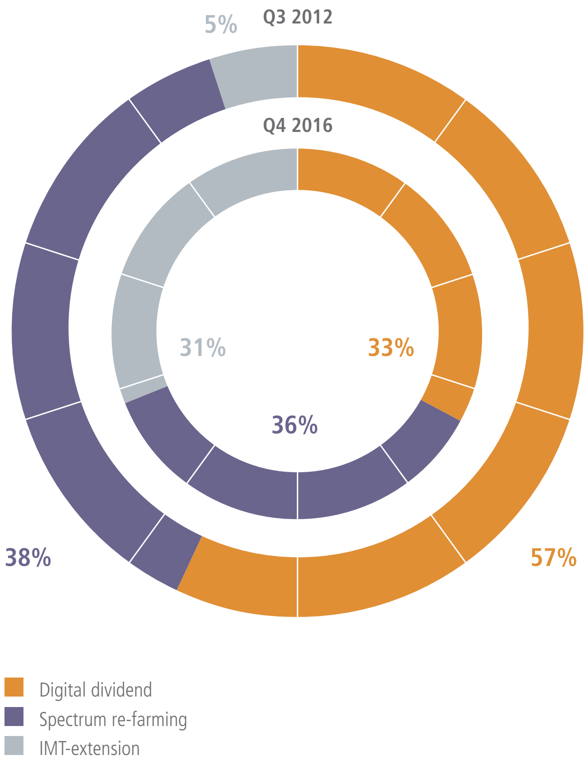


Figure 6: 4G LTE Spectrum Solutions as a % of Global LTE Connections
Source: Wireless Intelligence

The harmonisation of LTE spectrum bands globally:

- would enable radio component suppliers and device manufacturers to realise greater economies of scale
- would lower the cost of embedding connectivity for devices aimed at the global market (due to the possibility to use fewer radios), and
- would facilitate national and international roaming between operators (given common radio technology).

What does the future hold?

The mobile industry is in constant and rapid evolution

Rapid deployment of innovative products and services is essential to the mobile operator community which faces increasing market saturation and intense competition. Operators aim to continuously deploy better and more efficient cellular networks, while increasing coverage and mobile internet speeds. As described previously, mobile network technologies have evolved rapidly across the globe, with close to one third of the global market choosing to upgrade from GSM to WCDMA/HSPA to LTE.

LTE-Advanced represents the next technological step in the industry with operators already starting to deploy this technology – considered to be 'real' 4G standard by the International Telecommunications Union (the ITU). LTE-Advanced will offer downlink bandwidths of up to 1 gigabit per second and uplink speeds of up to 300 Mbps – dependent on the spectrum allocation.

This rapid technological evolution presents adjacent industries with something of a quandary: at what level of mobile technology should they engage?

However, one characteristic of most mobile technologies – including LTE-Advanced – is the backwards compatibility of networks and devices. This technological requirement ensures that users roaming on newer technologies will be able to fall back on to legacy networks depending on their available coverage. For instance, a consumer streaming video on an LTE-enabled smartphone will fall back on to legacy HSPA or EDGE networks once he/she moves out of the LTE coverage zone, thereby ensuring seamless continuity of service.

Network evolution is difficult to predict

It is quite difficult to predict how LTE networks will be deployed in any specific geography given that:

- Network evolution is based upon the commercial decisions of individual mobile operators which in turn is dependent on the core characteristics and needs of their customer base
- Spectrum is licensed at a national level generally for fixed periods (3G licenses, for example, have an average lifespan of 10-15 years) and the scope and timeline of spectrum auctions and licenses differ widely by country
- The LTE global market is still in its infancy and since LTE spectrum is fragmented across the globe, there remains a high level of uncertainty surrounding operator network deployments and migrations from 2G/3G to 4G LTE.

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

Leading network equipment supplier Ericsson recently estimated that 3G WCDMA/HSPA networks currently provide coverage to more than half of the world's population. It expects that figure to jump to 85% in five years as demand for mobile internet access increases and smartphones become increasingly affordable. Ericsson further estimates that LTE coverage will jump from 5% of the world population to 50% over the same period (see Figure 7).

While 2G GSM/EDGE has by far the greatest reach, covering more than 85% of the world's population to date, Wireless Intelligence expects 2G networks to only account for one third of the global connections market by 2020, as 3G/4G coverage expands. The analyst firm anticipates that 2G networks will account for an average of 45% of connections in both Africa and Asia by 2020. Meanwhile, in Europe and the Americas, 3G/4G networks are already widely used and the migration away from 2G networks is forecast to accelerate with 2G connections holding on to only 20% of connections in both regions by 2020 (see Figure 8).

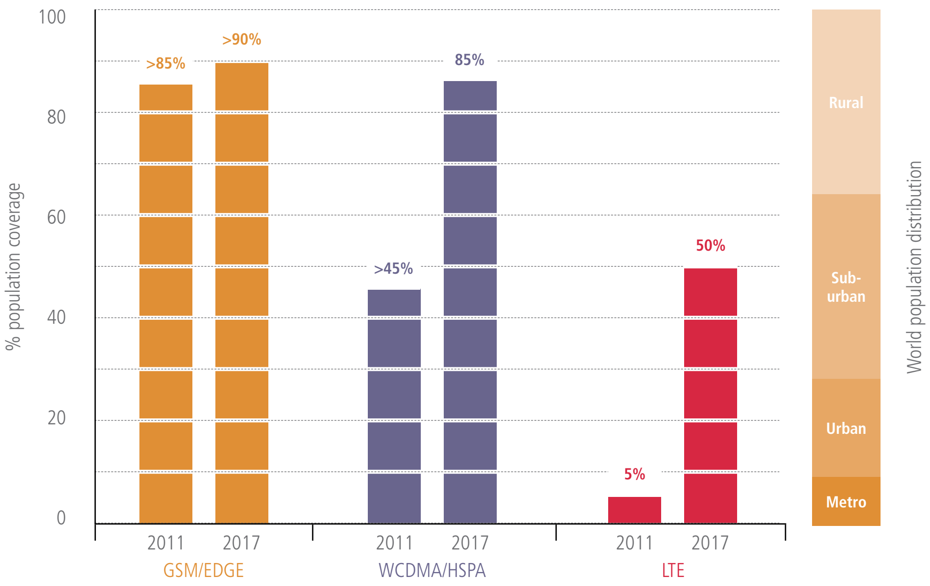


Figure 7: Ericsson's Coverage Estimates

Source: Ericsson's Mobility Report, November 2012

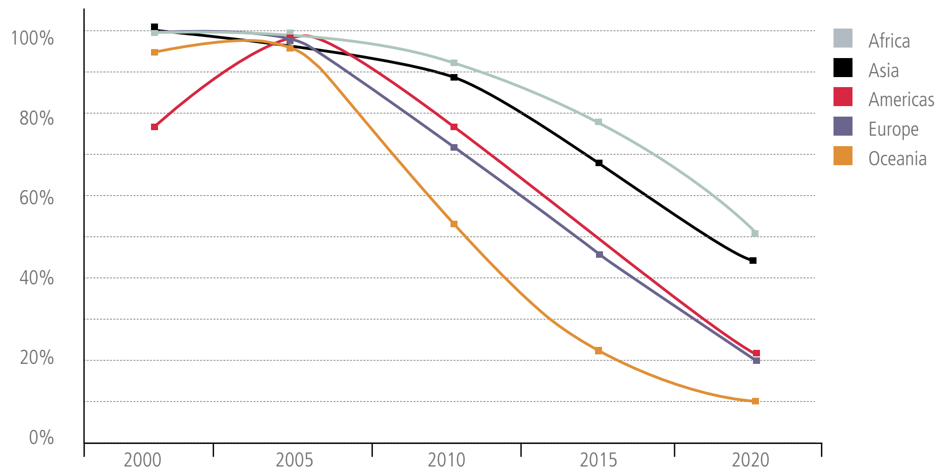


Figure 8: 2G connections as a % of Regional Connections

Source: Wireless Intelligence

	2G		3G		4G	
	2012	2017	2012	2017	2012	2017
AFRICA	88.8%	64.9%	11.2%	33.8%	-	1.3%
Middle Africa	96.1%	89.6%	3.9%	9.9%	-	0.6%
AMERICAS	60.2%	33.9%	36.6%	50.1%	3.3%	16.0%
Northern America	28.7%	9.8%	62.2%	54.8%	9.9%	35.5%
Southern America	76.8%	44.8%	23.2%	48.0%	-	7.2%
ASIA	79.3%	54.9%	19.8%	36.8%	0.9%	8.4%
Eastern Asia	67.8%	40.3%	29.9%	42.5%	2.3%	17.3%
EUROPE	60.0%	32.2%	39.6%	52.3%	0.4%	15.5%
Western Europe	50.8%	22.0%	48.8%	56.7%	0.5%	21.3%
OCEANIA	31.6%	16.2%	66.5%	60.3%	1.9%	23.5%
Australasia	23.7%	9.3%	74.2%	64.1%	2.1%	26.6%

Figure 9: Network Technologies as a % of Regional Connections
Source: Wireless Intelligence

Notwithstanding this complexity, the following table (Figure 9) provides a forecast of network technology share of regional connections over the next five years.

By 2017, Wireless Intelligence expects 3G to account for half of connections in the Americas (including North and South America) and Europe, while 4G will have reached close to one sixth of regional connections on average in both regions. Between 2012 and 2017, the share of 3G networks in Asia is set to rise to almost 37%.

Ericsson estimates that Asia's 3G WCDMA / HSPA population coverage is higher than the global average. It forecasts that 90% of the Asian population will be covered by 3G WCDMA / HSPA networks by 2017. Similarly, LTE coverage is set to reach higher levels (60%) in the region than the global average (50%) by 2017. Ericsson expects Asia to account for two thirds of the world's LTE population coverage in five years (see Figure 10).

In the US market, as the 4G LTE race accelerates, mobile operators are already preparing to shut-down legacy networks. With the vast majority (85% in Q2 2012) of its connections already on 3G, AT&T has announced that it will shut down its GSM network in 2017, allowing it to re-farm spectrum in the 1900MHz band for next generation services. The operator currently covers around 45% of the US population with LTE and expects to increase that figure to more than 90% by the end of 2014.

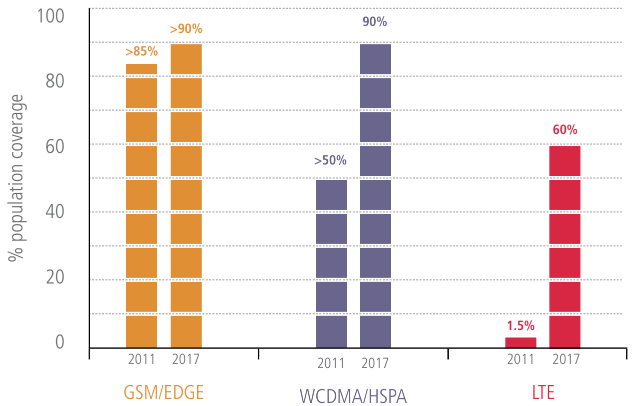


Figure 10: Ericsson's Forecasts for Mobile Network Coverage in Asia
Source: Ericsson's Forecasts for Mobile Network Coverage in Asia

Third-placed Sprint Nextel is implementing its 'Network Vision' initiative aimed at consolidating its network around 3G-CDMA and 4G-LTE, while winding down its iDEN push-to-talk network by Q2 2013, allowing it to free up spectrum in the valuable 800MHz band. Tier 2 operator, MetroPCS, hopes to eventually move its entire subscriber base to LTE, and plans to start refarming spectrum that it is currently using for CDMA traffic by the middle of 2013. Meanwhile, there has been speculation that market-leader Verizon Wireless – which already covers around 80% of the US population with LTE – could soon start repurposing CDMA spectrum bands for LTE. However, Verizon executives have been quoted as saying that the older networks will remain as they are for "a very, very long time" – possibly in order to support emerging M2M (machine-to-machine) markets.

In other regions, such as Europe, 2G network shut-downs are not on operators' agendas since 3G/4G still represented less than half of Europe's mobile connections in 2012 (40%) – compared with 73% in the US. Nevertheless, the GSMA expects LTE operators in the region to refarm their existing 2G spectrum for 3G/4G services. At present, a quarter of mobile operators in Europe have launched LTE networks, while Wireless Intelligence expects four out of five operators in the region to have launched LTE by 2017.

More broadly, despite the rapid migration towards 3G/4G, legacy 2G networks remain essential to preserve the current global roaming ecosystem. It is a basic roaming requirement that users can connect to voice services when out of 3G/4G coverage zones and/or when travelling to another country. Roaming represents a substantial source of revenue for operators which 2G networks will help to preserve for some time. In addition, mobile operators are likely to continue supporting M2M services running on 2G legacy networks.

Service awareness and Quality of Service – what is possible on mobile networks?

The growth of M2M services brings opportunities for mobile operators to provide connectivity and value-added services to a diverse range of customers and applications. Some mobile connected services may be very demanding (e.g. cash-in-transit vehicle security systems incorporating the capability to transmit video pictures and urgent alarm signals), while others may be very tolerant (e.g. periodic reporting of utility meter readings). Mobile network operators will be best placed to take advantage of the growing M2M opportunity, if they can:

- provide tiered quality of service (QoS) levels to meet service provider and end-user requirements in the areas of speed, reliability and availability
- measure delivered service levels
- ensure seamless service when devices or services are roaming
- charge based on QoS level.

To date, mobile network operators have not widely or commercially deployed standardised mechanisms for delivering different QoS levels on their own networks, and especially while roaming, due to their complexity and cost, and a lack of sufficient customer demand. Although not yet quantified, this demand is likely to grow due to requirements from various industry sectors (especially the automotive, health and utilities/smart cities sectors). This increased demand would create the incentive for mobile operators to offer a small number (e.g. 3-5) of service classes by investing in tiered QoS capabilities, or to take advantage of the QoS capabilities that will become available to them through 3GPP Release 7 (Policy & Charging Control) network deployments, which are likely to be introduced by many operators either to manage VoIP traffic or to support the introduction of LTE networks. The Release 7 QoS control approach for mobile data services is centred around the QoS Class Identifier (QCI), a parameter that gives network operators full control over the QoS provided for their offered services for each of their subscriber groups.

Extending the geographic availability of service classes to the roaming environment would be a natural next step for those roaming partners that are capable of supporting this functionality. Many mobile connected services will be offered internationally, and in many cases, devices may be permanently roaming. Although the Release 7 QoS control approach is fully supported when roaming, and although wholesale charging based on QoS can be supported by the existing billing (TAP3) standard with minimal effort, roaming partners would need to agree inter-operator tariffs (IOTs) per service class, increasing the complexity of existing roaming relationships.

In summary, service classes are not yet available from mobile networks, but once the technical enablers are in place and the market has evolved to show significant associated demand, mobile operators are likely to start offering service classes and tiered service levels.

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

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 factors

The form factor of the SIM card is evolving to support new business requirements. The removable SIM card form factors[4] commonly in use today 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.

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' – a physical implementation provides enhanced security. 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.

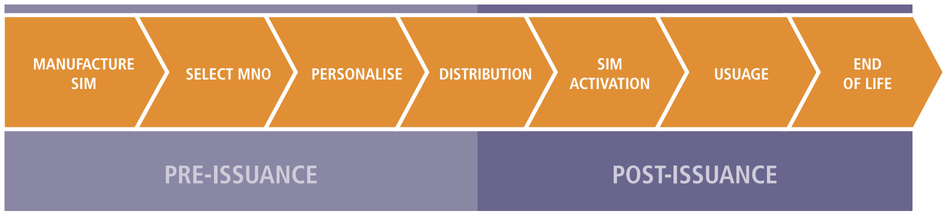


Figure 11: The Linear SIM Life Cycle Model of Today
Source: GSMA

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 (see Figure 11).

The use of the current generation of 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").

The standardised 'remote management' technologies available today do not facilitate the remote provisioning or switching of operator credentials on the SIM card. But the GSMA, along with a group of leading mobile operators, is driving the development and standardisation of a next generation of SIM card technologies

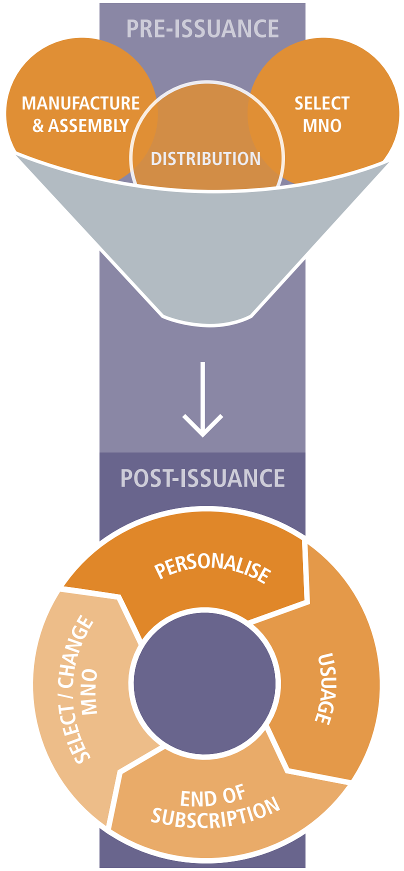


Figure 12: Outcome-Based SIM Life Cycle Model with Repeat Provisioning
Source: GSMA

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

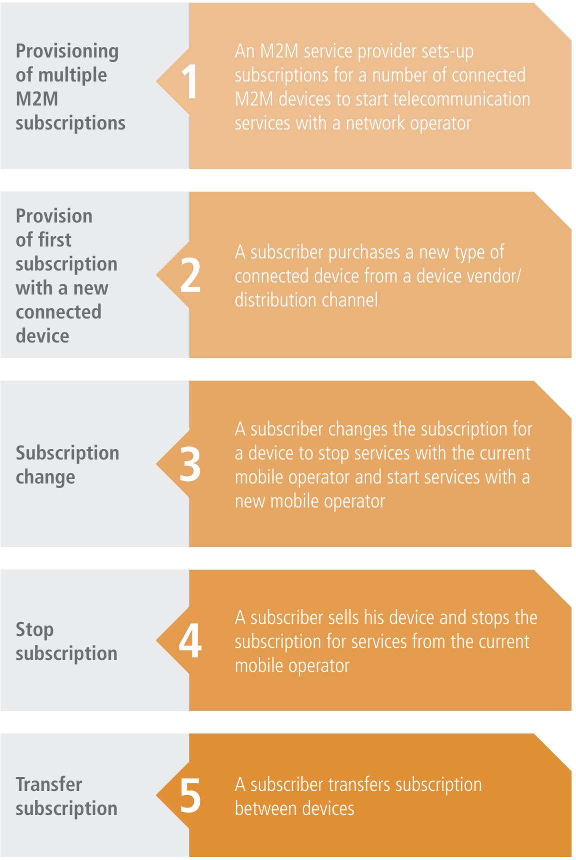


Figure 13: SIM Provisioning Use Cases
Source: GSMA

to facilitate the remote management of the operator credentials within the SIM. The goal of this initiative is to enable remote SIM management, helping drive global momentum for new, innovative and cost-effective connected devices that will enhance daily life, 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 (see Figure 12).

SIM Provisioning Use Cases

The GSMA has defined five primary use cases for the remote-provisioning of next generation SIMs (see Figure 13):

These SIM provisioning use cases are applicable to the automotive sector. Here are two examples of automotive scenarios:

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 its 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 its chosen mobile operator for vehicle testing and / or 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 sourcing mobile connectivity for 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 vehicle 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 vehicle 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 (Figure 14), which highlights the new role of the subscription manager.

Without a standardised subscription manager architecture, each mobile operator would have to use their own proprietary technical solutions for the remote personalisation of embedded SIMs. Difficulties would then arise when trying to switch a device which contains an embedded SIM between two operators who had implemented fundamentally different technical solutions.

Developing a standardised subscription manager architecture based upon common requirements and with common shared elements would resolve such issues whilst at the same time reducing cost and complexity.

A standardised solution will also drive the necessary economies of scale to ensure the successful deployment of the embedded SIM solution to the market.

The interfaces and processes needed to make an embedded SIM work are virtually identical to current SIM personalisation processes and interfaces used by mobile network operators. For many MNOs these interfaces are currently with SIM vendors and proprietary to each operator/group.

The subscription manager is responsible for the secure processes via which an MNO is able to personalise an embedded SIM 'over the air' (see Figure 15).

Benefits of remotely-provisioned SIM management

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

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

The technical standard contains sufficient flexibility to facilitate numerous business models: It is likely that business models will be developed through discussions between network operators and their customers.

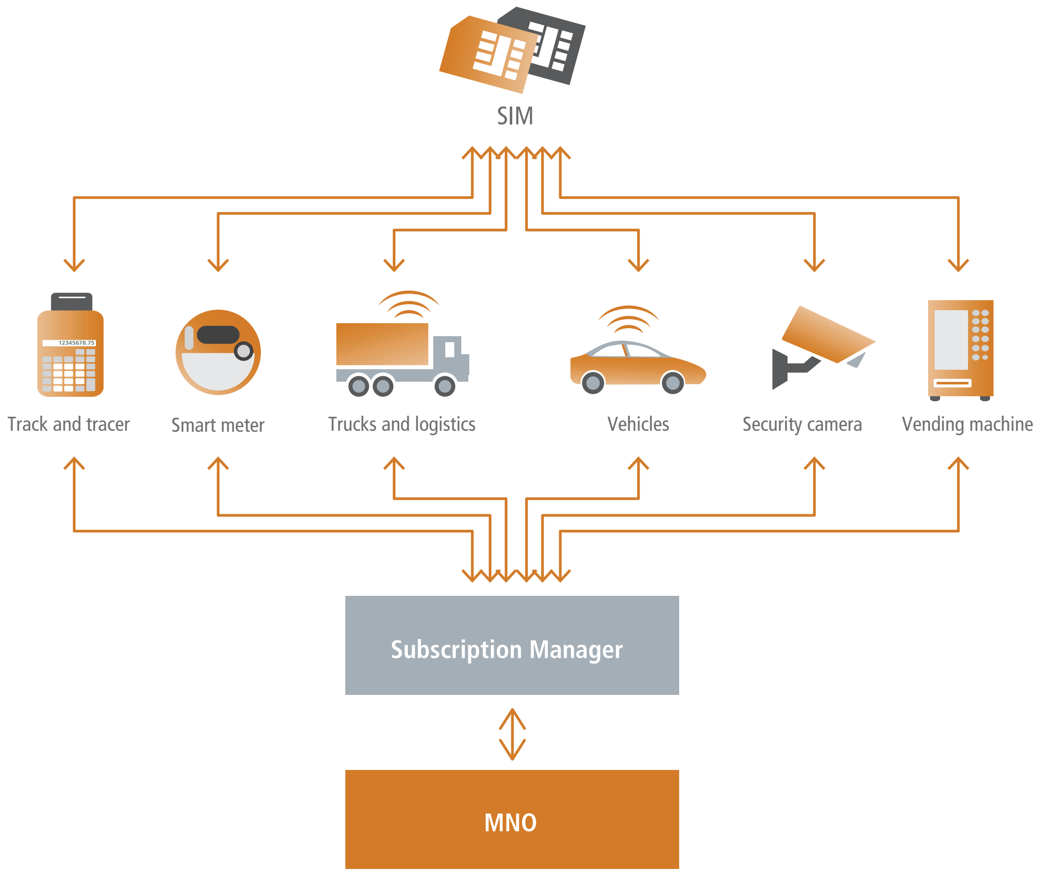


Figure 14: Remote Provisioned SIM: Elements
Source: GSMA

Status

The 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 implementation of a worldwide-embedded SIM standard, reducing fragmentation and driving scale for 'connected' devices across various industries, including automotive, consumer electronics, healthcare and utilities.

Next Generation Embedded SIM	■ Functionally-identical to a traditional SIM card ■ 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 MNO in the eUICC, as well as the selection of a new MNO 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 ■ Management and execution of MNO policy ■ Secure routing of profiles to embedded SIM
MNO	■ Uses subscription manager to manage profiles ■ Maximum re-use of existing provisioning interfaces and processes

Figure 15: The Elements Involved in Remote SIM Provisioning
Source: GSMA

The GSMA, and its partners, plan to show advanced 'proof of concepts' during 2013, with the first commercial deployments likely to follow in the near future.

Next steps for mobile operators

Mobile operators are seeking to better understand the automotive industry's requirements with respect to:

- How in-vehicle services, and their connectivity requirements, are evolving
- How to enable all appropriate connectivity options for services.

Greater understanding of these two aspects will facilitate the development of tailored approaches and services to support telematics and infotainment, in line with the underlying needs of automakers. Moreover, cross-industry collaboration will be required to overcome some existing ecosystem barriers. Mobile 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 types of connectivity
- 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.

Automakers' Connectivity Requirements

This chapter considers automakers' requirements for the development of connected car services. It covers:

- The general industry context
- Business models
- Embedded modules' characteristics and cost forecasts
- Different connectivity methods for providing in-vehicle services
- Performance factors for cellular technology for the delivery of specific services.

This chapter also discusses the inherent trade-offs involved in the different requirements and connectivity options. Finally, it explores the future evolution of infotainment, telematics and other connected car services.

The general automotive industry context

Automakers have very different industrial requirements from mobile network operators (see Figure 17). These differences help to explain some of the underlying challenges in cooperation.

One of the primary differences is the very different lifecycles for the development of automotive products (≈24-36 months) and the lifetime of the products (≈7 to 10 years), compared with the mobile operator lifecycle for the development of services (≈average of 6 to 12 months) and network development (1 to 3 years, with a desired 7 year minimum network operational lifecycle).

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

- Create durable solutions, which:
  - » require few hardware updates (given the difficulty of providing these updates across large number of dispersed users with embedded solutions)
  - » support over-the-air software 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)

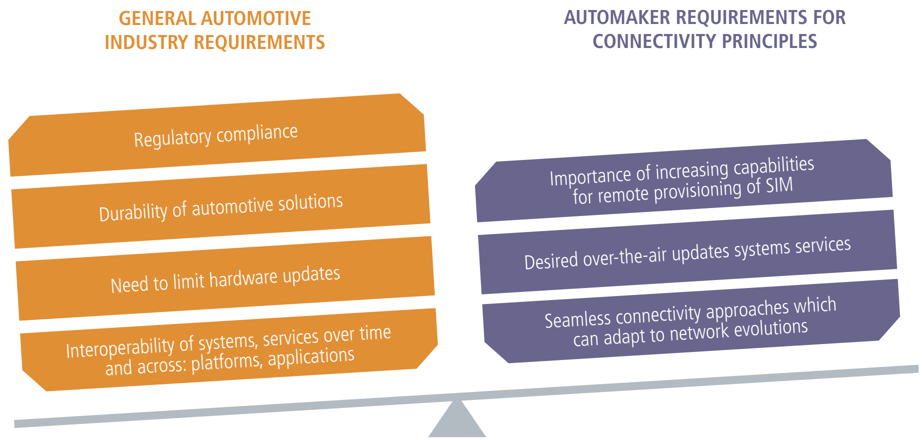


Figure 16: Basic Automotive Industrial Requirements
Source: GSMA

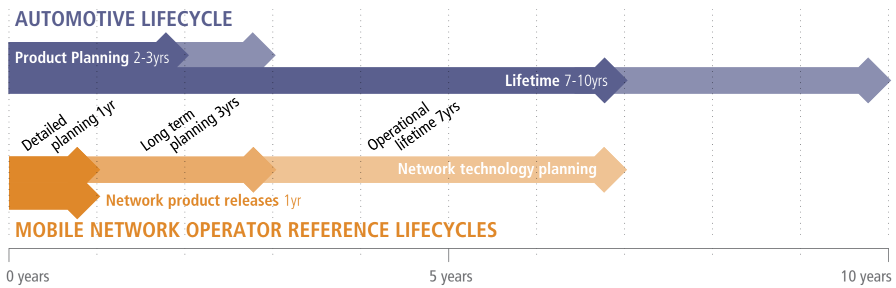


Figure 17: Differences in the Automotive and Operator Industrial Lifecycles
Source: GSMA

- Manage multiple connectivity approaches in a flexible manner to accommodate potential changes in user services during the lifecycle of the vehicle (changes of owners, countries of operation, etc.) and enable 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 the automotive sector.

Examples of upcoming connectivity regulations impacting the automotive sector

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 will result in wide-scale usage of connected vehicles in Europe.

Private third party emergency calls, which are proprietary value-add services (e.g., Volvo OnCall, GM OnStar, PSA, Fiat, BMW ConnectedDrive), are likely to continue to exist.

Many of the standards for eCall are either approved or under final approval (see Figure 18).

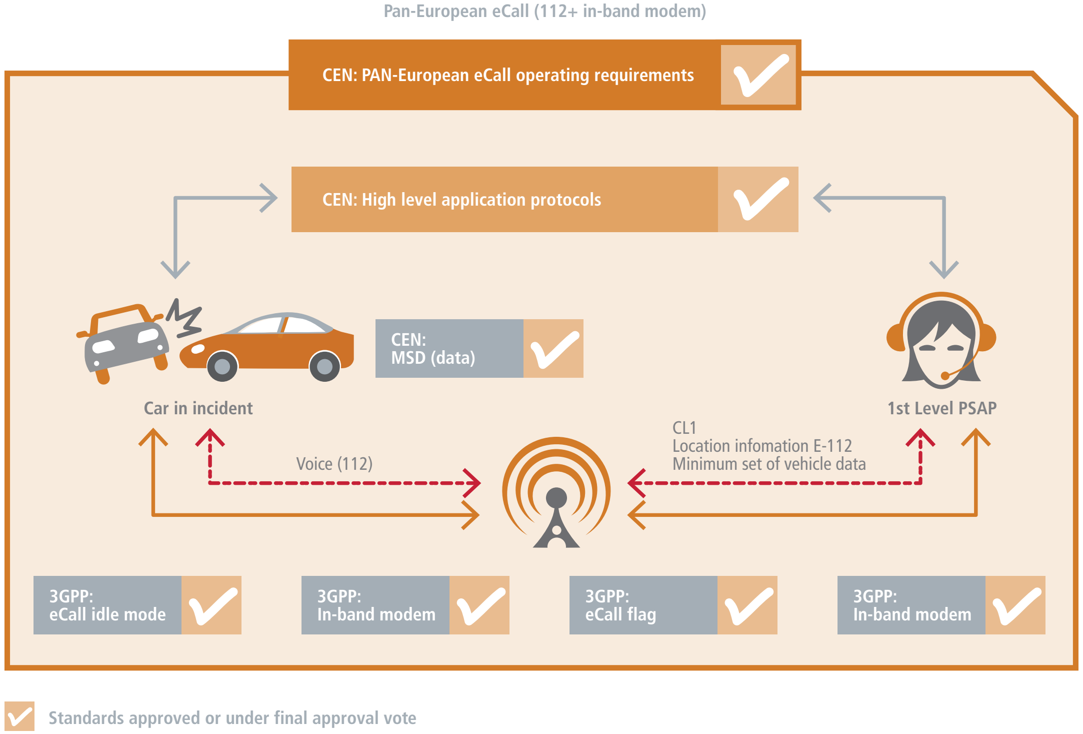


Figure 18: eCall Standardisation Process
Source: GSMA

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.

MOBILE OPERATORS

A European Commission Recommendation (8 September 2011) requires operators:

- to implement the eCall discriminatory "flag" in all networks
- to route eCalls to the Public Safety Answering Points
- to handle eCalls as any other 112/E112 emergency call.

MEMBER STATES

A European Commission Recommendation (8 September 2011) requires Member States:

- To define emergency call infrastructure to receive the eCalls
- To communicate the most appropriate public safety answering point to route eCalls
- to report to the Commission on the implementation status by 31 March 2012.

Common specifications for Public Safety Answering Point (PSAPs) within the framework of the ITS Directive are set to be issued by the end of 2012, which will ensure emergency centres and rescue services are equipped for processing the data transmitted by the eCall.

AUTOMAKERS

Vehicle Type Approval Legislation is set to be issued by the end of 2012 to ensure that all new cars in 2015 will have to be equipped with eCall devices complying with agreed European standards (already approved by CEN and ETSI).

Figure 19: Regulatory Framework for eCall
Source: GSMA

The European Commission Recommendation on eCall (8 September 2011) has outlined the different requirements and responsibilities for mobile operators, Member States and automakers (see Figure 19).

ERA-GLONASS (Russia)

Russia has also begun implementing an emergency call service, which builds upon elements of the European eCall system, extending the approach to include additional features such as GLONASS GNSS positioning (Global Navigation Satellite System) and a back-up data transmission mechanism using SMS.

The main characteristics of ERA-GLONASS, which different from those of eCall, are:

- GLONASS GNSS must be supported, but combined GNSS receivers (e.g. GLONASS/GPS) are acceptable
- Data transfer mechanisms include in-band modem (primary mechanism), SMS (back-up communication channel) and GPRS
- Echo cancellation and noise reduction requirements have been defined
- ERA-GLONASS calls for vehicles to be able to initiate a test session and be able to transmit the test results to the back-end systems. Test mode is intended for testing the functionality of the in-vehicle system (IVS). The operation is identical to eCall mode, but voice calls are forwarded to a dedicated call centre, and the mode identifier field in emergency data set is set to "test"
- The IVS can be configured and upgraded remotely
- The IVS can be pre-installed (terminal installed on the automotive assembly line) or retrofitted (the terminal is installed at service centres or at dealer centres after vehicle assembled at automotive assembly line)
- The terminal shall record acceleration profile before and during the crash. The crash profile is transmitted as a separate block of data
- Support for a standardised I/O port and standardised communication protocol to connect additional sensors.

The schedule for deployment is:

- Back-end ERA-GLONASS systems are scheduled to be operational by Q1 2014
- The first deployments, scheduled for October 2014, will be targeting the transportation of dangerous cargo and collective passenger transportation.

All new passenger vehicles (e.g. automobiles and light vehicles) will be required to have the ERA-GLONASS in-vehicle system (IVS) installed from January 2015.

SIMRAV (Brazil)

Brazil has been developing legislation since 2006/07 to support the SIMRAV anti-theft system. A regulation coming into effect by 31st January 2013, will give automakers 12 months to fit the system to all new vehicles.

SIMRAV's objectives are:

- Reduce vehicle theft and lower vehicle insurance rates
- Provide consumers with the opportunity to opt-in during vehicle lifetime for anti-theft services from any service provider.

The approach for SIMRAV is:

- Mandatory incorporation of anti-theft equipment by auto and motorcycle manufacturers into all new vehicles (commercial, passenger, motorcycle) destined for the Brazilian market. SIMRAV will, therefore, be incorporated into 5 – 7 million new vehicle sales
- Anti-theft service subscription offered by certified service providers (i.e by "TIVs")
- Based upon an MVNO approach in which Denatran (Ministry of Cities, Department National Transit)/Serpro (The Federal Service for Processing of Data) (under an outsourcing arrangement):
  - » Manage an home location register with default profiles for inactivated service subscriptions
  - » Conduct an over-the-air switchover between the pre-loaded Serpro profile and operator profile when service subscription is active.

EU Roaming Regulation

A new European Roaming Regulation, adopted in June 2012, introduces the following measures (which are driven by the consumer handset market):

- 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 new roaming regulation on automotive services are not evident at this point. However, the pressure to reduce roaming costs in the EU is clear.

Considerations for driver distraction

Driver distraction is an important risk factor for accidents and the role of mobile phones in this regard has been the subject of extensive research and regulation. In 2011, the World Health Organization (WHO)[7] produced a report on this topic concluding:

'It is now evident that if you are using a mobile phone while driving you are approximately four times more likely to be involved in a crash than a driver who is not using a phone. This risk appears to be similar for both hand-held and hands-free phones, because it is the cognitive distraction that is an issue, not only the physical distraction associated with holding the phone. Text messaging appears to have an even more severe impact on driving behaviour and crash risk.'

At an international level, Article 8.6 of the Vienna Convention on Road Traffic, 1968, was amended in 2006 to include a ban on the use of hand-held mobile phones while driving and this is reflected in many national road rules. In addition, some countries have imposed extra restrictions on certain groups of drivers, generally young/inexperienced or commercial drivers.

In December 2011, the US National Transportation Safety Board[8] called for a nationwide ban on non-emergency 'driver use of portable electronic devices (PEDs) while operating a motor vehicle' unless the devices are 'designed to support the driving task'. However not all countries are convinced of the effectiveness of bans and a 2012 report for the Swedish National Road and Transport Research Institute (VTI)[9] recommended against a general ban on phone use, preferring instead driver education, information and technical solutions.

	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

Figure 20: Comparing Different Types of Car Connectivity
Source: GSMA

The GSMA's position[10] recommends against activities that involve drivers taking their eyes off the road. Both operators and automakers have been active in efforts to promote compliance with national laws and responsible mobile phone use by drivers. There are many examples of educational campaigns, often aimed at particular driver segments such as inexperienced drivers.

Some phone features, such as voice-operated dialling and other speech-based applications, can minimise the physical distractions associated with mobile phone use. Technical solutions have also been developed, such as software applications that prevent phone use or disable certain functions (for example, texting) when the vehicle is in motion.

Research into driver distraction shows that driver's attention and therefore driver's performance depends on a concept of "workload" i.e. the amount of information one has to process in order to make decisions. If the workload is too low –

7 http://www.who.int/violence_injury_prevention/publications/road_traffic/distracted_driving/en/index.html

8 http://www.ntsb.gov/news/2011/111213.html

9 http://www.vti.se/

10 http://www.gsma.com/publicpolicy/mobile-and-health/mobile-devices/mobile-phones-and-driving/

for example, when driving on an empty road, attention wanders affecting driving performance, on the other hand, during bad weather, or on a busy or unknown intersection, the workload is too high. Reliable workload models that are based on processing car data, as well as maps and traffic information, can be used as an input to intelligently regulate flow of information, HMI layout and other features making it safer and more rewarding to use connected devices and services. Greater cooperation between automakers and the mobile communications industry could ensure more effective solutions and potentially the development of a 'driver mode' analogous to 'airplane mode'.

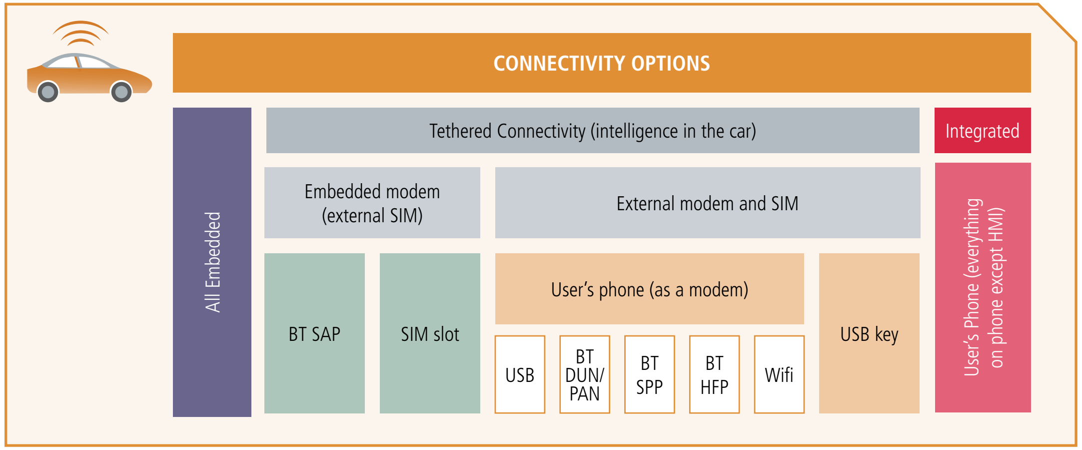


Figure 21: Different Means to Enable Car Connectivity:
Source: SBD 2011

In February 2012, the US National Highway Traffic Safety Administration[11] (NHTSA) issued voluntary guidelines to encourage automakers to limit the distraction risk for in-vehicle electronic devices installed at time of manufacture that require visual or manual operation by drivers. These guidelines could be examined by the Connected Car Forum to determine their relevance in other markets.

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).

Each of these different connectivity options relies upon different mechanisms for linking the car to cellular technology. The primary options are summarised in Figure 21.

The utilisation of these different connectivity options differs across the various in-car 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, or bCall, services). Embedded solutions covering a broad range of services have generally been limited to premium vehicles, with some notable exceptions:
  - » Volume brand manufacturers, such as BMW, General Motors, Peugeot, Renault, and Roewe, offer services based on embedded solutions in entry models and up
  - » Where region-specific regulations exist for embedded solutions (such as eCall in Europe).

[11] http://www.distraction.gov/

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 future. A tandem approach might be used, for example, when the technology employed for the embedded system is likely to be inappropriate for newer-generation or higher bandwidth services.

The use of different connectivity solutions also reflects automakers' desire to differentiate between the:

- Costs for services that they have a direct interest in (such as remote diagnostics)
- Costs for large bandwidth, frequent use services (such as infotainment).

If it was possible to differentiate between these services through split billing, automakers would be likely to dramatically reduce the employment of tethered solutions.

Embedded solutions

All of the connectivity (module and SIM) and the intelligence are built into the car. Figure 22 shows the strengths, weaknesses, opportunities and threats related to embedded solutions.

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

Figure 22: Strengths, Weaknesses, Opportunities and Threats for Embedded Connectivity Solutions
Source: GSMA

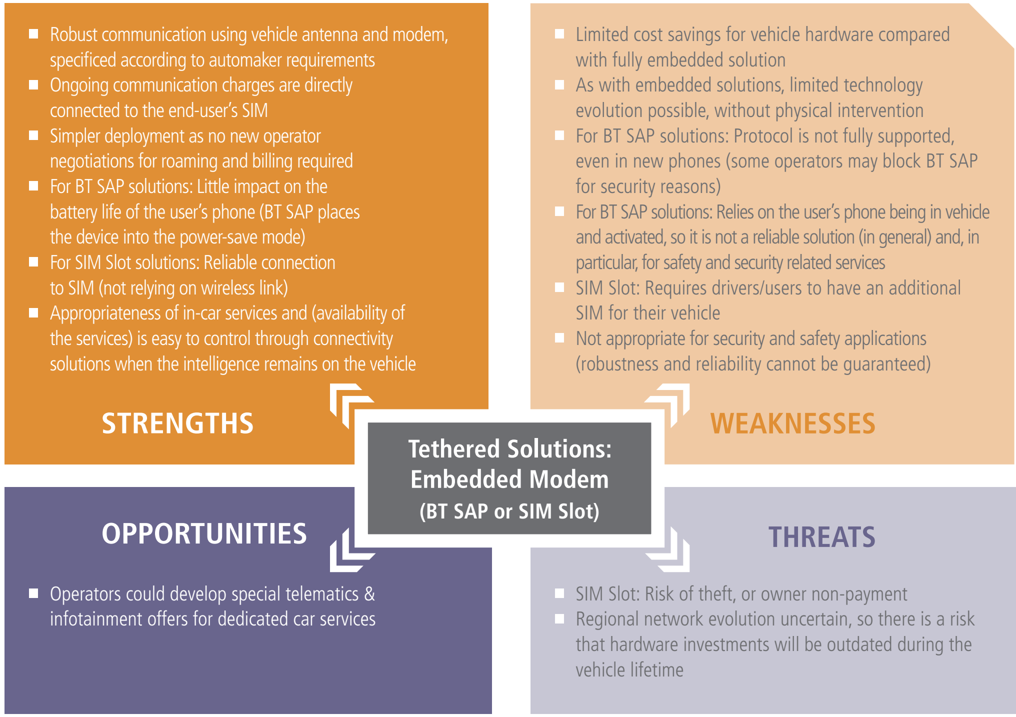


Figure 23: Strengths, Weaknesses, Opportunities and Threats for Tethered Connectivity Solutions (embedded modem with intelligence in the car)
Source: GSMA

Tethered solutions

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. There are multiple ways to enable tethering, such as:

- An embedded modem, which employs the user's existing SIM (via the Bluetooth SAP profile[12] or a SIM SLOT) solely for connectivity
- An external modem, which utilises the user's phone (via USB cables, Bluetooth profiles (DUN/PAN, SPP/HFP) or WiFi) or USB modem, tethering for both the connectivity and the modem.[13]

Figure 23 shows the strengths, weaknesses, opportunities and threats related to tethered solutions, in which the modem and intelligence is embedded in the vehicle.

A 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 need for the user to activate their phone or insert their SIM.

Figure 24 shows the strengths, weaknesses, opportunities and threats related to tethered solutions, which combine an external modem with intelligence embedded in the vehicle.

As Figure 24 shows, tethered solutions, using an external modem, have the benefit that:

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

This approach, however, requires that the necessary 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.

12
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).

13
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.

Tethered: External Modem

STRENGTHS

- Up-front hardware costs in vehicle are reduced
- Communication costs are directly tied to user
- Allows user's connectivity solutions to follow their handset device evolution (high replacement rate); keeping pace with network technology upgrades (avoiding obsolescence and, therefore, likely to provide faster performance as available)
- Direct links (USB cables, or sticks) also avoid the difficulties of having to use wireless protocols
- When USB modems are deployed, data and voice (on the user phone) can be used in parallel and is likely to result in 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 modem could provide failover and support to the car systems
- Appropriateness of in-car services and (availability of the services) is easy to control through connectivity solutions when the intelligence remains on the vehicle

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
- The communications module is 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 linked to automaker, even when related to the mobile device
- Tethered solutions can be incompatible with SMS-based services
- Operators are not able to create specific offers for connected car services run through phones
- Not appropriate for security and safety applications (robustness and reliability cannot be guaranteed)

OPPORTUNITIES

- Additional functionality, such as apps and maps etc., can be embedded into a USB modem, thereby addressing download and usability issues
- Operators could develop specific solutions (such as dedicated USB connections) for connected car services

THREATS

- Threats
- Durability of the connection interface could be a problem for long term solutions
- Some operators discourage, charge extra 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

Figure 24: Strengths, Weaknesses, Opportunities and Threats for Tethered Connectivity Solutions (external modem and intelligence in the car)
Source: GSMA

Integrated connectivity solutions

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 25 shows the strengths, weaknesses, opportunities and threats related to integrated connectivity solutions.

The smartphone integration approach is particularly appropriate for user-based services, such as infotainment or access to traffic information and external navigation. Moreover, the technologies are likely to remain up-to-date and there is a direct allocation of service costs to the end user. However, it can be a risky solution given the limited control the automakers have on the applications and services used. It is also an unreliable solution for safety and security solutions, given the need for the user to activate 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 products.

The different approaches can be used in a complementary fashion in the same vehicles. A number of vehicle manufacturers launched smartphone integration solutions in 2012, with the main focus being on providing the driver with access to internet radio, streaming music 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 white paper, the management of data costs can be 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 various 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
- Honda has adopted a USB dongle in Japan.

These solutions are characterised by the pros and cons outlined in Figures 23 and 24, 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. Many 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.

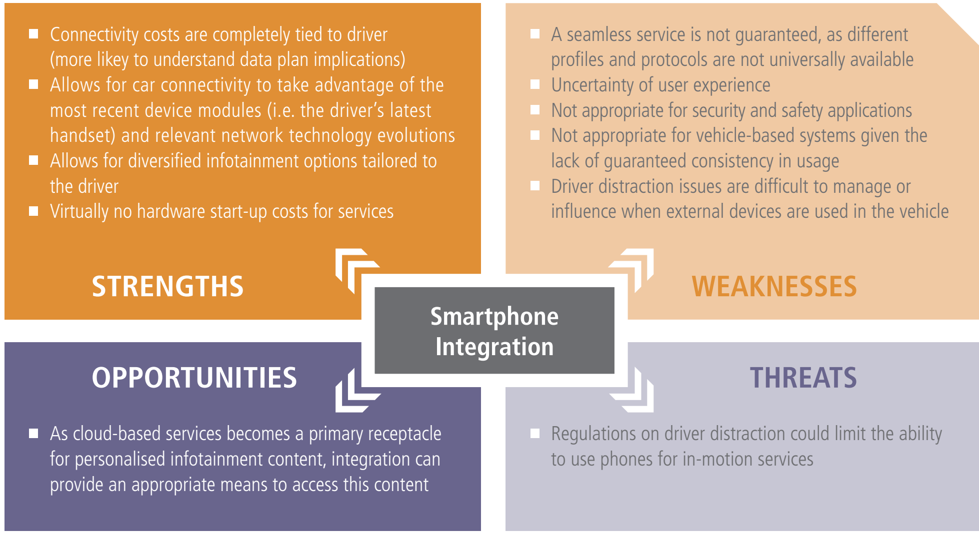


Figure 25: Strengths, Weaknesses, Opportunities and Threats for Smartphone Integration Connectivity Solutions (in which only the HMI runs on the car, everything else is on the phone)
Source: GSMA

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.

To address this issue the Connected Car Forum is assessing the recommendation of a single set of profiles and protocols for tethering to reduce complexity and harmonise a standard approach to tethering to remove the existing obstacles.

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 for mobile operators 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 effective option for increasing car connectivity.

Connected Car Services	**Mobile Network Requirements**	**Digital Pioneers** (Australasia, East Asia, Nordics, North America)	**Connected Players** (Western Europe)	**Fast growers** (China, Central America, Eastern Europe, Middle East, Russia, Southern Africa, Southern America, South-Eastern Asia)	**Discoverers** (Nigeria, Other Africa, Southern Asia)
Infotainment: Higher Bandwidth	4G/LTE	4G and LTE deployed and services currently available	Spectrum likely to be widely available in 2-3 years	4G spectrum identified for roll out, probably beyond 2016	4G services expected beyond 2020
Infotainment: Lower Bandwidth	3G	Spectrum available and likely to remain available for next 10 years			Inconsistent roll out of 3G likely for the next 5 years
Navigation	3G				
Telematics – Vehicle-Centric	2G	Re-farming of 2G spectrum a possibility in these markets over the next 5 year time span. This would mean that 4G services would use spectrum currently allocated to 2G; with 2G chipsets no longer supported.		2G likely to remain available for the next 10 years	
Telematics – Other	2G				

Figure 26: Spectrum Availability for Connected Car Services
Source: GSMA

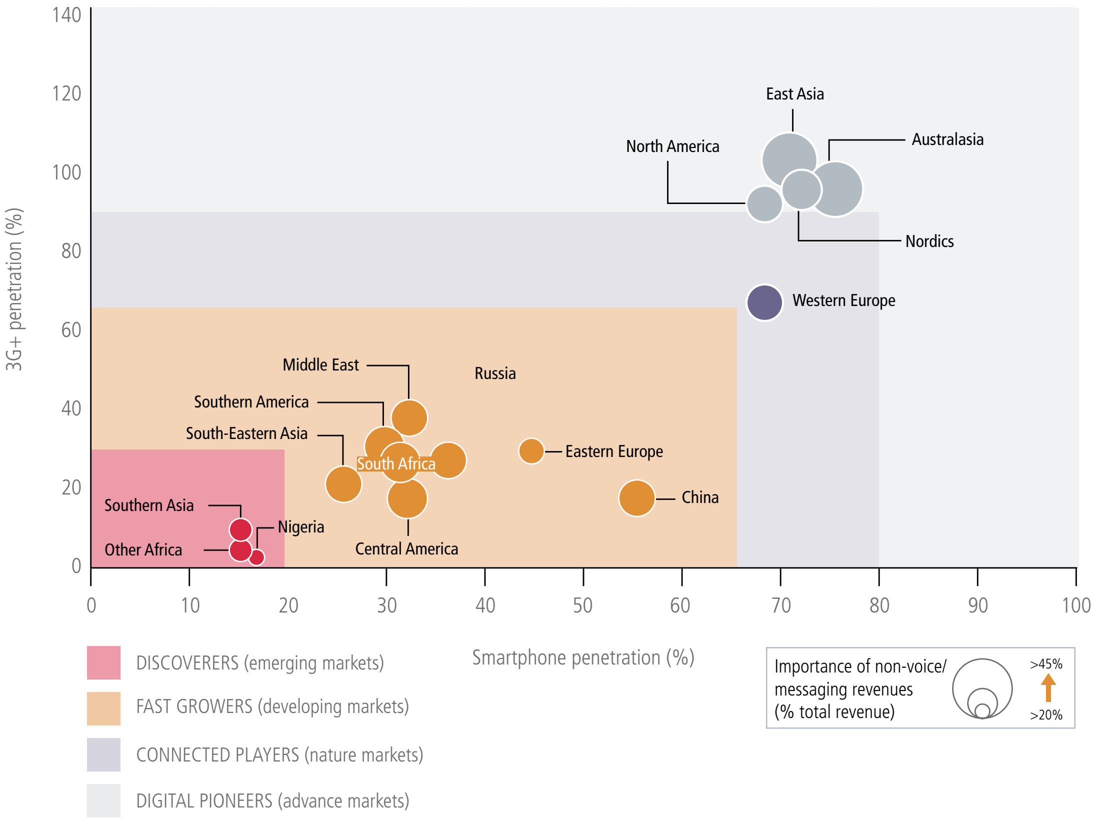


Figure 27: Global Mobile Markets Maturity[14]
Source: GSMA

Network evolution considerations for connected car services

To make it easier to understand how mobile network evolution relates to the different types of connected car services, the GSMA Spectrum Programme has defined four geographic segments of the global mobile market: Digital Pioneers, Connected Players, Fast Growers and Discoverers. The table below (figure 26) shows the predicted spectrum coverage for the different service types and technology network requirements.

The GSMA has segmented the four categories of the global mobile market by maturity and technology adoption level. The level of 3G+ penetration (see Figure 27) shows that the number of 3G+ connected devices in some regions (the Digital Pioneers) has already exceeded the population. These regions have also deployed 4G-LTE.

14 Population split is based on 65 sample countries, fixed at 2011 levels. 3G penetration: 2012 Q2 forecast based on 2012 Q1 actuals and historic figures: Wireless Intelligence. % non-voice/messaging ARPUs – based on Ovum data 2011. 2010 are actuals, 2011 and beyond is forecast (includes all mobile broadband and VAS service revenues). Smartphone penetration – based on Strategy Analytics data from 2011. 2010 are actuals, 2011 onwards are forecasted.

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 after a brief "trial" usage period (typically three to 12 months).

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.

Automakers are also exploring alternative business models involving subsidies, advertising and additional Business-to-Business (B2B) services. Furthermore, some automakers are taking into consideration the internal benefits derived from the services (such as increased customer loyalty) when making a business case for connected car services. However, such factors are either still under investigation or are only contributing a small amount to the overall business case.

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
- careful selection of the network access technology.

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 is 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.

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, there is a risk 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 (such as permanent 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.

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 mobile 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.

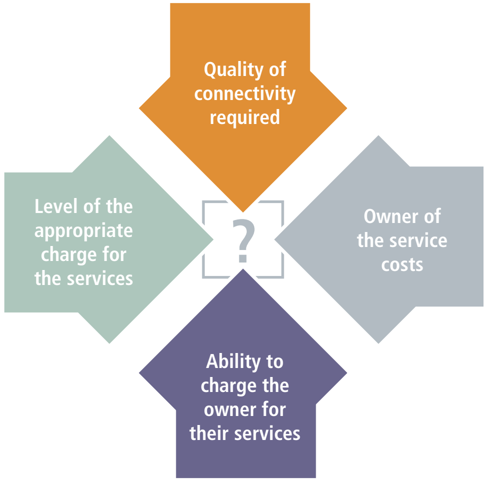


Figure 28: Automotive Considerations in Managing Cost of Data-Related Services
Source: GSMA

Retrofitting solutions are necessary when new technologies are required to support a 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 participate (based on network choice and / or subscription plan).

Furthermore, the automotive industry tends to have very specific requirements with respect to product quality, support and delivery processes. Additionally, there is a need 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 appropriate stage in the 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 with consumer electronics modules), are listed:

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
- 2 year or longer vehicle warranty (compared to 3 to 12 months for consumer electronics).

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 product development 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 a vehicle.

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 in Figure 29.

Factors impacting the evolution of automotive–grade modules

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

Automotive Module Technology	2011	2013	2015
2G	30	25	20
2G/3G (WCDMA or CDMA EVDO)	65	59	55
LTE/3G/2G	N/A	120-150[16]	80

Figure 29: Celluar Module Core Technology Market Prices (in US$)[15]
Source: GSMA

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

16 Figure 29 shows the average price for a basic automotive platform, which has additional requirements over normal industrial M2M modules, based upon estimates made at the 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.

- 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
- 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%).[17] 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 connectivity 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.

Analysys Mason found that 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.[18]

Choosing an appropriate connectivity module

Clearly, automakers have to account for a large number of factors 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 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).

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.

17 Analysys Mason, Berg Insight, ABI "Mobile Connectivity: Comms Module Price Development".

18 Analysys Mason's Report on The Total Cost of Ownership for Embedded Mobile Devices, (11 November 2010, Reference 17974-455), page 19.

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. On the basis of 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, are likely 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 guarantees about the future availability of 2G in Europe for the reasons outlined 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.

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 over-the-air capabilities via an M2M cloud platform benefit modules

As the M2M market grows, so does the maturity and intelligence of M2M cloud platforms, enabling intelligent devices, back-end systems and cloud platforms to seamlessly integrate.

A M2M cloud platform could bring about a global solution for managing connected devices across different networks and interfaces. This is attractive to the end-user-facing brand (typically the automaker) as it enables the performance of the device on the network to be visible and troubleshooting processes to be performed.

A M2M cloud platform could provide the following management services:

- Subscription management – manage in real time the subscription to the mobile network, activating or deactivating the SIM to manage it through the lifecycle of the M2M device
- Monitoring – an M2M platform has the possibility to monitor key parameters and communication traffic of a group of devices, to configure them, and to remotely send AT commands
- Upgrading application software and firmware – upgrading one or multiple devices in the field through one click on the M2M platform web portal simplifies the management of devices and reduces operating costs, removing the need of any physical action on the device in the field when an upgrade is required
- Accelerate app development – an M2M cloud platform can offer a range of readily-available elements which accelerate the application development process, allowing products to come to the market faster and reducing development costs.

What is an automotive grade module?

The automotive environment requires fail-safe components that can withstand multiple conditions, such as extreme temperature ranges and high physical stress. In particular, they need to comply with:

- The automotive temperature grade (-40/+85°C minimum for full operation, with respect of ETSI minimum values)

- The PPAP (Production Part Approval Process) – The purpose of the PPAP is to ensure that suppliers of components comply with the design specification and can run consistently without affecting the customer line and improving the quality systems
- 100% compliant with automotive environmental quality requirements.

In practice, automotive grade connectivity modules also need to:

- Withstand the automotive environment without performance degradation for the average life of a vehicle estimated at 15 years/150,000 miles
- The module should be able to withstand common causes of field failures to reduce the need for expensive repairs
- Bridge the gap between the automotive lifecycle (years) and handset lifecycle (months) because redesigning components is not an option
- Be produced using stringent manufacturing processes and change control.

Notwithstanding these requirements, it may be more cost-effective and quicker to create a variant of an industrial product rather than creating a connectivity module specifically for the automotive environment from the ground-up.

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).

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 in Figure 30.

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 highlight the pressing 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.

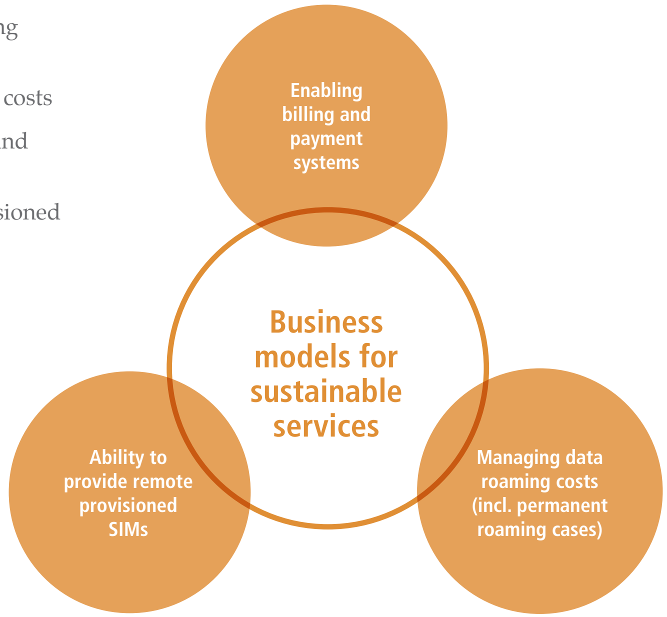


Figure 31: Important Role of Enablers in Supporting Business Models for Telematics and Infotainment Services
Source: GSMA

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 Production	Initial vehicle production where automaker pays for telematics	SIM is provisioned to the mobile 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 mobile 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 mobile 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	Automaker can provision SIM to their local mobile operator	Automaker service contract	Infrequent
	Traveller roaming: Car is travelling temporarily from country A to country B. Subscription is changed from local MNO in country A to local MNO in country B	Automaker can provision SIM to their local mobile operator	Automaker service contract	Every hour/ day/week
Customer Service Changes	Vehicle owner changes MNO (where owner pays for telematics services)	Customer can provision SIM to their new mobile operator	Customer contract/ automaker service contract	Every year
	Car is sold to a new owner (where owner pays for telematics services)	New owner can provision SIM to their mobile operator	Customer Contract/ automaker service contract	Every year
	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 mobile operator	Customer contract/ automaker service contract	Every hour/ day/week

Figure 30: Automaker Use Cases for Connectivity

Source: GSMA

Process	Connectivity Use Case	Use Case Characteristics Description	Owner of Connectivity Contract	Expected Frequency of Use Case
Service cancellation	Service subscription is stopped	Automaker or customer can cancel subscription	All possibilities	Infrequent
Hardware changes	Operational problem: Telematics control unit (TCU) fails	SIM in new TCU can be provisioned to same MNO 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 MNO as required	All possibilities	Once
Revision of large scale connectivity strategy	Automaker changes MNO (e.g. for commercial reasons)	Automaker can provision the SIM to a new MNO	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 MNO to/from the customer's MNO. Transfer subscription	Automaker service contract	Infrequent
Revision of large scale connectivity strategy	MNO merger/acquisition: MNO A merges with MNO B. Automaker is currently with MNO B. Automaker changes subscription from MNO B to preferred MNO X since involvement of MNO A is not seen as beneficial	Automaker can provision SIM to new mobile operator	Automaker service contract	Very infrequent
	Initial MNO goes out of business where automaker pays for telematics	Automaker can provision SIM to new MNO	Automaker service contract	Very infrequent

Figure 30: Automaker Use Cases for Connectivity

Source: GSMA

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, five primary types of billing have been mooted by automakers to unlock the potential for telematics and infotainment business models (see Figure 32).

- **Service-based billing:** providing billing based on a service rather than one bill for a month's usage
- **Split billing:** being able to allocate cost against a service or a location or a time of day
- **End user billing:** Being able to bill the end user or interact with other payment methods
- **Retail billing:** Be able to add other items to the bill
- **Service control:** Being able to manage the availability of the service

Figure 32: Types of Billing Desired by Automakers
Source: GSMA

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
- responding to end users' preferred payment approach (such as pay-as-you-go versus subscription; consolidated billing for multiple services versus separate bills).

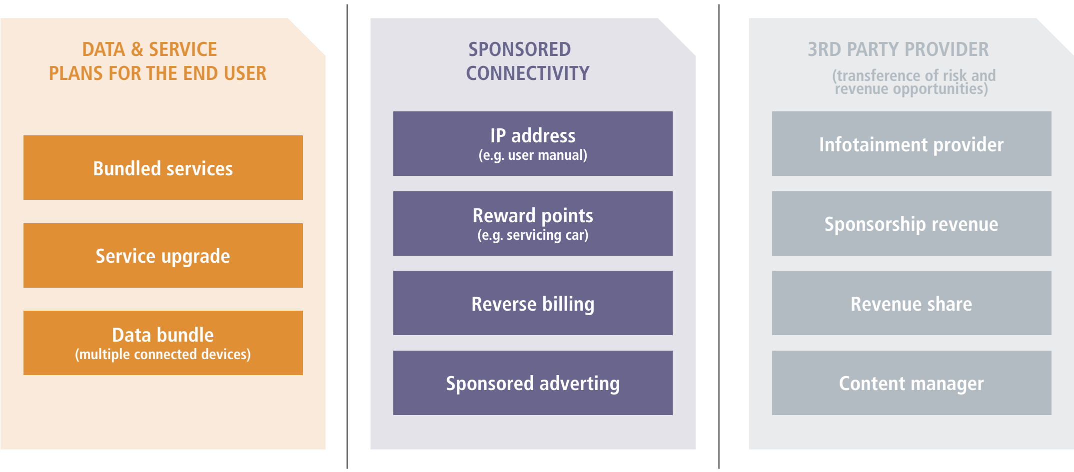


Figure 33: Business Models Enabled by Split Billing and Charging Capabilities
Source: GSMA

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 a defined period or 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).
- Sponsored services that are billed to a third party provider that is sponsoring the cost of connectivity for the use of their services (such as download of audio books).

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

Split billing and charging has also been recognised by the GSMA Connected Car Forum as an essential enabler for new business models (see Figure 33).

Example use cases and scenarios

Use Case – Sponsored connectivity

Scenarios:

- **Rewards scenario:** a customer receives an amount of data for their connected car service if they use the automaker's servicing center. The cost of the data is covered in the servicing price (could be internally automaker billed or directly to the dealership / service centre)
- **Sponsored internet navigation to specific IP addresses:** Automaker sponsors internet services for their online user manual (to avoid printing manual).

Use Case – Third party infotainment content

Scenarios:

- The automaker offers audio / video content from third party suppliers (the only audio and video download service accessible in the car) and the connectivity costs are covered in the single cost for downloading the data
- A third party is providing a radio streaming service in the car and the cost of the service also includes the connectivity cost.

Remotely-provisioned SIM

The next generation embedded SIM, explained in the previous chapter, would help to address a number of the requirements outlined in the automotive connectivity use cases, including remote and 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.)
- 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.

The 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).

Requirements related to specific services

The next section of this white paper analyses the primary categories of telematics (12 service types) and infotainment (4 service types) – see Figure 34. These services already exist in various deployment forms across the globe, with telematics being more widely deployed than infotainment.

The general status of telematics and infotainment services today

Figure 34 outlines the range of telematics and infotainment services that 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 services 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
  - » multimedia, internet services in a pervasive manner.

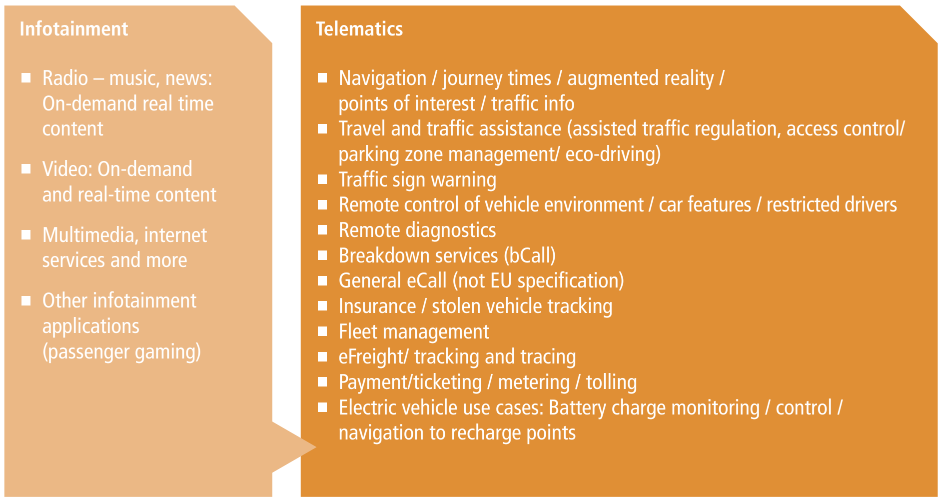


Figure 34: Primary Telematics and Infotainment Services
Source: GSMA

Specific service characteristics

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

- The 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 35 shows the characteristics of the different telematics and infotainment services.

	Service Characteristics				Transmission Type			
Services	**Type of Service**	**Continuity of Demand**	**Max. Potential Frequency**	**Service Delivery Responsiveness**	**Voice**	**Data**	**Voice and Data**	**Bandwidth Range**
Radio: music, news: on-demand real time content	On-demand	Irregular	Several times per day	real-time		X		>64kbps
Video: On-demand and real-time content	On-demand	Irregular	Several times per day	real-time		X		>1Mbps
Multimedia, internet services and more.	On-demand	Irregular	Several times per day	near real-time		X		>1Mbps
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 per day	near real-time		X	X	<1Mbit/usage
Remote diagnostics	Pull	Irregular	Weekly/ 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	real-time			X	<1Mbit/usage
Insurance/stolen vehicle tracking	Pull	Regular	Several times per hour	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[19]	Pull	Irregular	Several times per day	near-real-time		X		<1Mbit/usage

Figure 35: Importance of Connectivity Criteria Per Service
Source: GSMA

19 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 to be presented to the driver. This is an evolution of the existing (non-telematics) on-board sign recognition systems that recognise a limited set of signs. The use of the greater computing power of an off-board server could allow any sign in any country to be recognised.

What are automaker technology requirements for specific services?

Six 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 move across geographically; this movement is dictated by the road network rather than population density (one of the primary factors governing network deployment)
- **High bandwidth:** 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
- **High 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.).

Figure 36 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 (ECC): This criterion determines the suitability of the cellular network technology to support the individual service (i.e. the criterion which is most restrictive in the selection of appropriate network technology)
- Very important (VI)
- Important (I).

Legend: ECC = *Essential constraining criteria;* VI = *Very important;* I= *Important*

	Wide Coverage	High Band-width	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	I	VI	I
Insurance / stolen vehicle 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

Figure 36: Primary Importance of Technology Criteria for Telematics and Infotainment Services
Source: GSMA

Mapping the different technology criteria to individual services illustrates:

- The primary role of coverage for all telematics services
- 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 services 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.

How to choose the right technology, based upon regional coverage

The other primary selection criterion, for deploying telematics and infotainment services, is network coverage in a specific region of the world. 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:

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

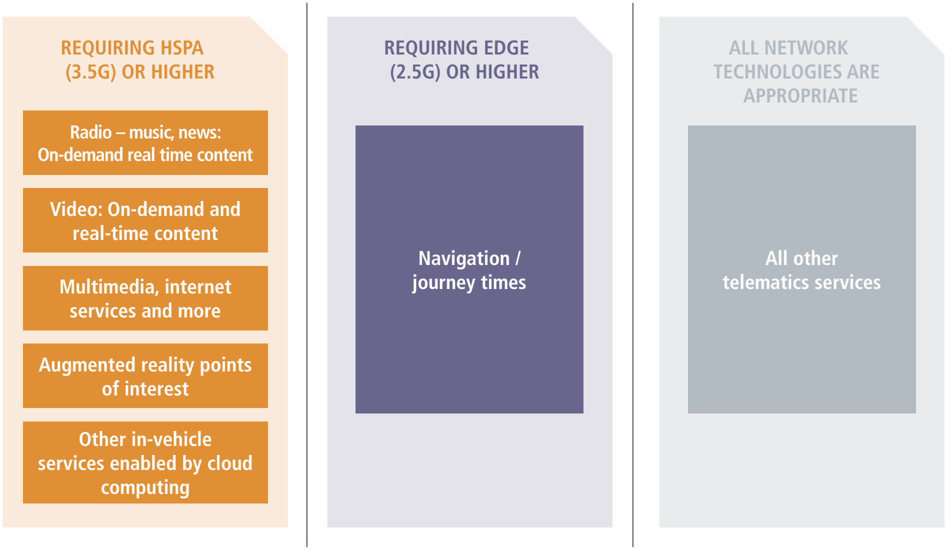


Figure 37: Classification of Telematics and Infotainment Services by Bandwidth and Latency Requirements
Source: GSMA

Current coverage

As discussed, coverage varies significantly in 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. Yet, as described previously, 3G WCDMA/HSPA networks are expected to cover more than 85% of the world's population in five years, up from just over half in 2012. In addition, LTE is expected to cover half of the world's population in five years, up from 6% this year.

Considerations for the future of regional coverage

The viability of 2G network technology as a solution for telematics services in some regions, such as Europe and North America, 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 would 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.

As discussed earlier in this report, the likely timeline for the viability of LTE varies by region, with aggressive roll-outs planned for:

- Developed Asia-Pacific
- North America.

How telematics and infotainment services are evolving

Usage of all of the categories of telematics and infotainment services is likely to grow in the next decade.

In 2011, Machina Research conducted a market sizing study (*Machine-to-Machine (M2M) Communication in the Automotive Sector 2010-20*), which forecast major growth (see Figure 38) in both telematics and infotainment services between 2010 and 2020.[20]

[20] Machina's 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'.

[21] 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'.

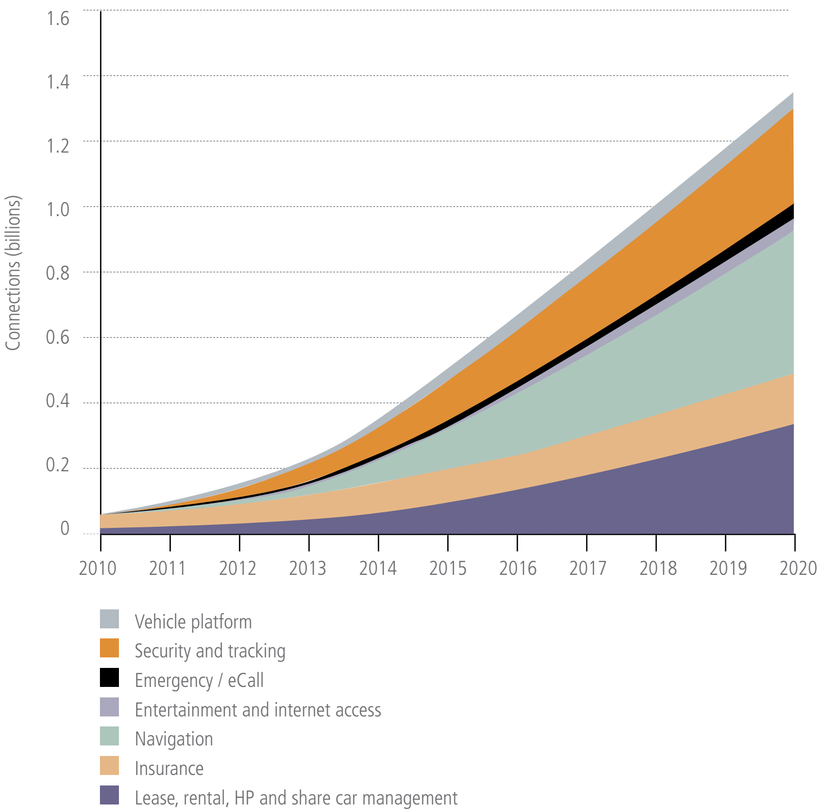


Figure 38: Machina Research's Automotive Forecast for Global M2M Connections [21]
Source: GSMA

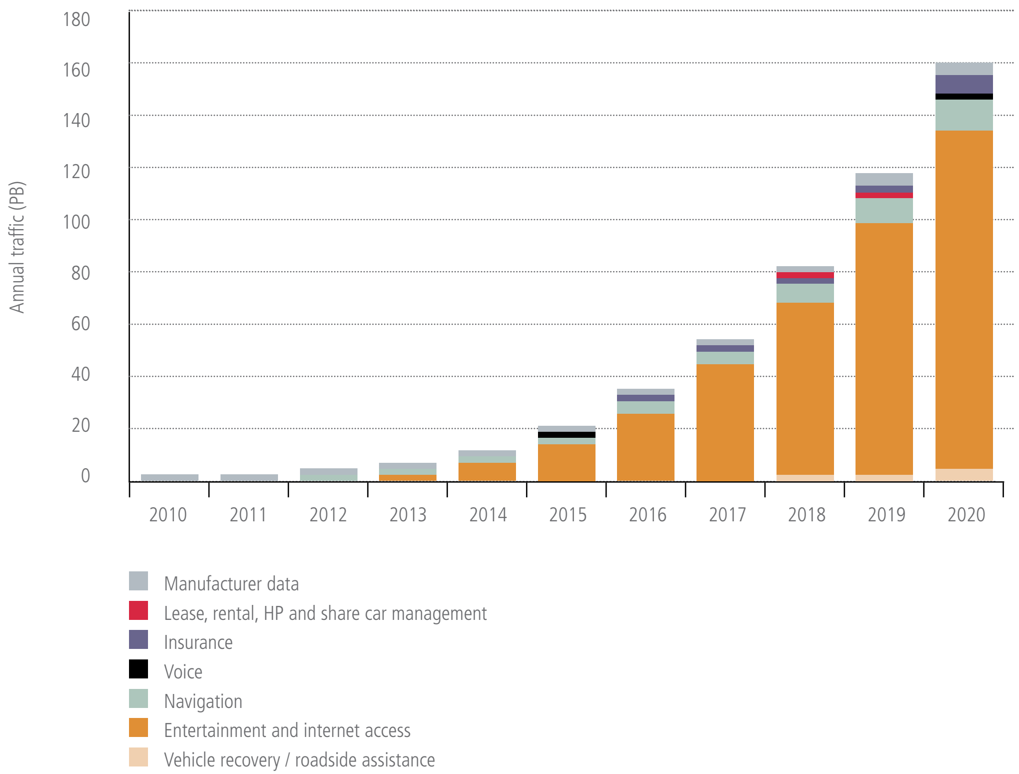


Figure 39: Forecast for Global Wireless Traffic Generated by Embedded Mobility by Application
Source: Machina Research 2011

Although the Machina growth forecasts include aftermarket devices, they capture the exponential growth of the sector overall.

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 high-availability apps (such as eCall and bCall)
- Infotainment and video services are expected to grow exponentially.

Machina's forecast for global wireless traffic generated by embedded mobility in the automotive sector shows entertainment and internet access driving an exponential increase (see Figure 39).

Enabling apps in the car

One of automakers' priorities 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 and tablet 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[22] may provide some level of commonality across automakers, but 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 Mercedes, Renault, GM and PSA, but this is still quite an immature market.

Integrating voice controls and built-in control devices, such as centre stack and driving wheel buttons, with apps running on user's mobile devices, enables automakers to take advantage of the creativity and rapid development cycles of the app ecosystem and build additional revenue streams and service offerings.

22 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.

Automakers can partner with mobile operators and multiple data and service providers to harness the internet connectivity and additional computing power provided by rapidly-evolving smartphones and tablets to innovate quickly and create cloud-based offerings.

One of the key challenges for automakers is to decide which operating system to adopt for their in-car platform. They also need to decide on:

- whether to wait for a browser-based solution, such as HTML5
- whether to develop an app store-style environment for offering new apps
- 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 is a topic 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
- 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 the deployment of ad-hoc non-cellular technology. The use of mobile technologies, such as HSPA and LTE, has been studied and brought to standardisation, as enabling technologies for the information exchange between:

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

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 since June 2011. It also suggests key topics for future cooperation between automakers and mobile operators.

Preface

The further evolution of telematics and infotainment services depends on increased collaboration between automakers and mobile network operators: These 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 in adjacent industries, such as the automotive sector. The speed of this evolution means that it is practically impossible to predict the technology that will be prevalent and widespread in mobile networks 20 years from now. This uncertainty 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.

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 from multiple geographies to the table
- 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.

Where could cross-industry cooperation continue to be beneficial?

Based upon these discussions, further areas for potential cross-industry cooperation have been identified. They are generally classifiable into three categories (see Figure 40):

- 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.

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.

Priority areas for cooperation between operators and automakers

Although there are a large number of potential areas of cooperation, the GSMA recommends immediate cooperation between operators and automakers in these areas:

- Business interfaces for remotely-provisioned SIMs (including automotive proof-of-concept),
- Developing joint initiatives with MNOs, automakers and SIM vendors, showcasing automotive use cases and inputting recommendations to the standardization process
- Regulation: Developing understanding and support of issues arising from new regulations in the automotive sector, providing regular updates about the status of the different regulations, agreeing on a common interpretation of the regulations and using the Connected Car Forums' agreed inputs to feedback formally to regulators. Establishing a knowledge pool (covering privacy) for the industry
- Business models: Developing arguments showing the real internal benefits of connected cars in term of internal efficiencies and internal savings for automakers
- Charging principles (in domestic and roaming scenarios) to support service-based billing and split billing

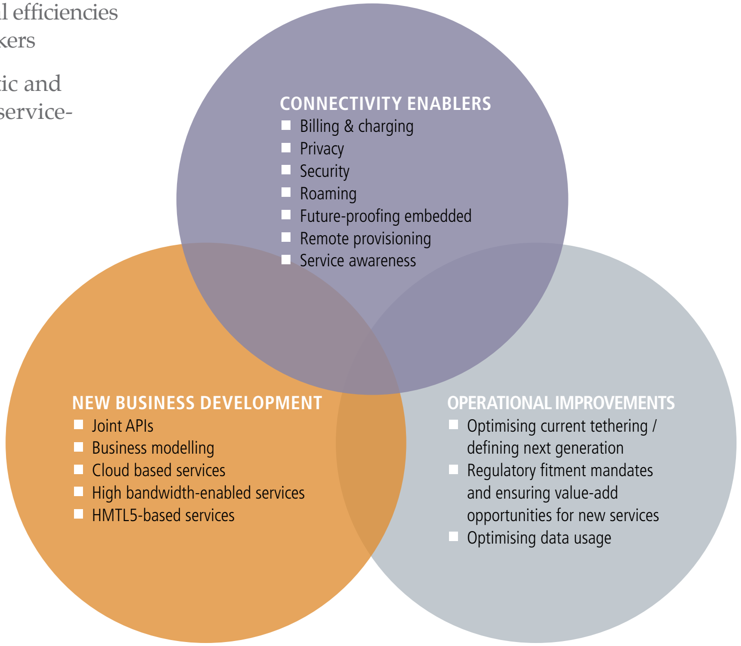


Figure 40: Breadth of Potential Joint Cooperation Areas
Source: GSMA

- Tethering: Overcoming technical barriers by delivering recommendations and guidelines to be promoted to the ecosystem (MNOs, automakers, terminal vendors) enabling interoperability and a standardized approach.

Who should be involved in these cross-industry activities?

Key global players in the primary geographies – Asia-Pacific, Europe and North America – from both the automotive and the mobile 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 mobile operators), such as tethering.

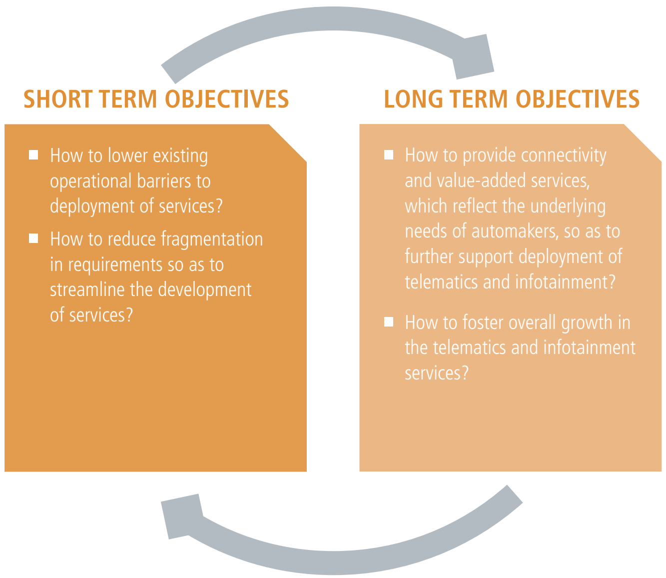


Figure 41: Principle Means to Improve the Telematics and Infotainment Services through Cross-Industry Action
Source: GSMA

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
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 in the context of this report 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 – European Telecommunications Standards Institute
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
An 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 to and from mobile devices.

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, such as position, fuel level, or alarm notification status, to be sent to a remote end user.

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 an operator to embedded SIMs. Note – the full role 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 tremendously 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 almost 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 be 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 goes beyond that typical in some adjacent industries, such as the internet or computing sectors. This support has traditionally been provided via call centres, but is increasingly moving online 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 provided 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. At present, 2G GSM/EDGE networks cover close to 90% of the world's population.

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

3G is available in 80% of the 236 countries worldwide as there remain some nations where the government has yet to license 3G spectrum. 3G WCDMA/HSPA networks cover just over half of the world's population to date while the penetration is expected to reach 85% in five years. 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 most cases 3G is deployed in the 2100MHz spectrum band . To achieve the equivalent geographic coverage, networks in the 2100MHz band require 5 to 10 times the number of cells required for networks 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+ use the same spectrum as WCDMA, 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 mobile broadband network or as a complementary technology to their LTE deployments. The motivation to deploy increased HSPA coverage is far greater than that for WCDMA, since the service experience is better for the consumer and has been widely embraced.

Global LTE coverage today is low (although some developed countries already have high urban coverage, e.g. USA and South Korea), 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. 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 gains greater economies of scale, 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 transmission speeds from 238kbps to 2.048Mbps (if EDGE Evolution is used, although this has only recently been deployed). These are theoretical maximums and the real achievable 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 connect voice calls to that used on 2G and 3G mobile networks – instead of using circuit-switched technology for voice, Voice over LTE specifies that voice calls are delivered via a technology called IMS, using a service definition developed by the 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 the frequency band rises. 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 influencing the service received by the customer. The quality of the reception provided by 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 provided by 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. In order to effectively deploy LTE modules in automobiles, enhanced, multiple antennas will be required to derive maximum performance especially at higher velocities.

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 spectrum predominantly harmonized around the 900 MHz and 1800 MHz frequency bands. 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 900MHz band) 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 both developed and developing markets, while around 50 developing countries are still awaiting commercial 3G services to date. However, as 3G spectrum has been harmonized internationally, the cost of 3G chipsets has eroded rapidly making 3G handsets and data-devices fairly affordable. 3G spectrum can be used for WCDMA, HSPA and HSPA+.

LTE requires new and additional spectrum to be licensed. The two primary spectrum bands for LTE are the 'digital dividend' at 700MHz or 800MHz (dependent upon market) and the IMT-extension band (2.5-2.6GHz). 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, notably in Europe. This spectrum is also being licensed by countries elsewhere in the world with varying timelines.

There are two variants to LTE technology, namely FDD (Frequency Division Duplex) and TDD (Time Division Duplex). The latter variant is being deployed in 2.5GHz spectrum band. The future of TD-LTE – and more specifically the availability and affordability of TD-LTE devices – is dependent upon the adoption of the network technology in China and India, which will drive TD-LTE global economies of scale. Chipset manufacturers are developing multi-mode FDD/TDD chipsets to facilitate interoperability and regional roaming capabilities.

There is also considerable interest in the re-farming of existing 2G spectrum in the 1800MHz band to use for 4G LTE services.. According to Wireless Intelligence[23], re-farmed spectrum in the 1800MHz band currently accounts for almost 40% of the global LTE market and will continue to do so over the next four years.

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 refarming 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. Refarming 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 refarm is not straightforward since any customers that are currently dependent upon the band identified for refarming 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.

23 Wireless Intelligence, *Spectrum refarming at 1800 MHz key to LTE device adoption*, published in September 2012.

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.

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 SMS technology 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 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 became available around the same time as 3G (WCDMA) 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 WCDMA roll out). However, today many networks support EDGE, although not always with the same degree of geographical coverage as GSM/GPRS.

3G – WCDMA

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 limitations of 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, equipped with web browsers, that a true internet experience equivalent to a fixed broadband connection would be realised.

For all of this, 3G networks are now widely deployed, but they have been transformed into HSPA networks, and thus the performance of the typical WCDMA 3G network is greatly improved.

3.5G – HSPA and HSPA+

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. 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 smartphones' support for e-mail, social networking applications and a swathe of other ways to enable the customer to 'stay connected' or to view content (including videos) while 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 advance 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 peak speeds in excess of 600Mbps in its most extreme incarnation.

According to Wireless Intelligence, HSPA had 600 million worldwide connections by end of 2011 and the growth in HSPA connections (at the end of 2011, running at around 19 million per month) shows no sign of slowing. Wireless Intelligence[24] further identified a significant decline in the number of WCDMA-only devices in operator portfolios over the past two years as these were replaced by HSPA-enabled devices, reflecting the fact that HSPA now accounts for more than three-quarters of 3G connections worldwide. Furthermore, almost all data devices (dongles, tablets, mobile hotspots, laptops) are now 3G compatible, with nine out of ten HSPA-enabled.

According to Ericsson, all WCDMA networks worldwide have been upgraded with HSPA. Furthermore, around 75% of HSPA networks have been upgraded to a peak downlink speed of 7.2 Mbps or above and approximately 50% have been upgraded to 21 Mbps or higher.

4G – LTE

LTE is being marketed by many operators around the world as '4G', but this is not strictly true. As per the ITU classification, LTE is in fact an evolution of IMT-2000 technology and hence comes under the 3G categorisation with WCDMA, HSPA, HSPA+ and other technologies mentioned previously. The ITU concluded that IMT-Advanced and WiMAX2 should be defined 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 as 4G.

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. 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 more than 200 operators worldwide in five years.

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[25] and is on a slow growth trajectory. In the next two to three years, LTE will become a major technology in the industry with WCDMA and CDMA operators both moving towards LTE as a common end goal.

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, China and other regions employed a technology called CDMA2000, whilst operators in Japan chose to use PDC.

Alternative 3G technologies

As with 2G, North American operators in some cases preferred to implement an alternative technology – CDMA2000 EV-DO

24 Wireless Intelligence, *3G technologies reshaping mobile device market*, published in April 2012.

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

Rel.0. This technology was also adopted by other operators in South Korea, India, Australia, New Zealand and some other markets. However, several operators – notably in Brazil and Australia – have chosen to migrate from CDMA to WCDMA. 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 CDMA2000 EV-DO Rel.0 can extend these networks in the same way as WCDMA operators can extend to HSPA. The EV-DO technology flavours available are Rev A and Rev B, which are roughly analogous to HSPA and HSPA+.

China Mobile, the world's largest operator by connections, 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 others on the world telecom stage.

Regional deployment details

The following table (Figure 42) depicts forecasts by Wireless Intelligence (the GSMA's research arm) of network evolution by 2015 in terms of connections 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 rollout of LTE[26]
- 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.

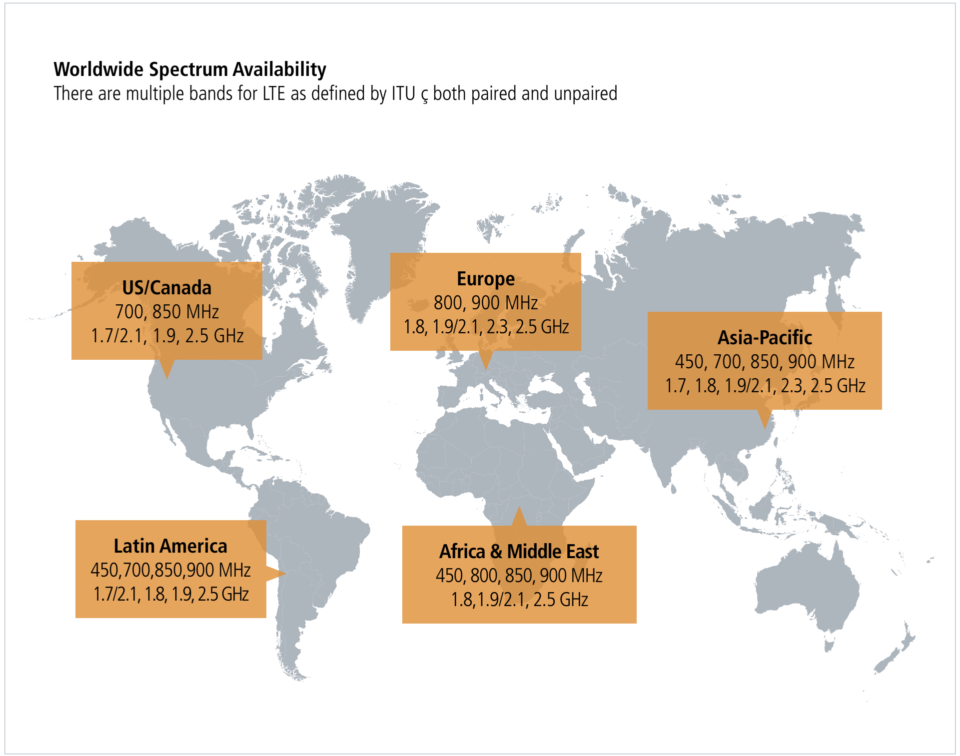
	2G		3G		4G	
	2012	2017	2012	2017	2012	2017
AFRICA	88.8%	64.9%	11.2%	33.8%	-	1.3%
Middle Africa	96.1%	89.6%	3.9%	9.9%	-	0.6%
AMERICAS	60.2%	33.9%	36.6%	50.1%	3.3%	16.0%
Northern America	28.7%	9.8%	62.2%	54.8%	9.9%	35.5%
Southern America	76.8%	44.8%	23.2%	48.0%	-	7.2%
ASIA	79.3%	54.9%	19.8%	36.8%	0.9%	8.4%
Eastern Asia	67.8%	40.3%	29.9%	42.5%	2.3%	17.3%
EUROPE	60.0%	32.2%	39.6%	52.3%	0.4%	15.5%
Western Europe	50.8%	22.0%	48.8%	56.7%	0.5%	21.3%
OCEANIA	31.6%	16.2%	66.5%	60.3%	1.9%	23.5%
Australasia	23.7%	9.3%	74.2%	64.1%	2.1%	26.6%

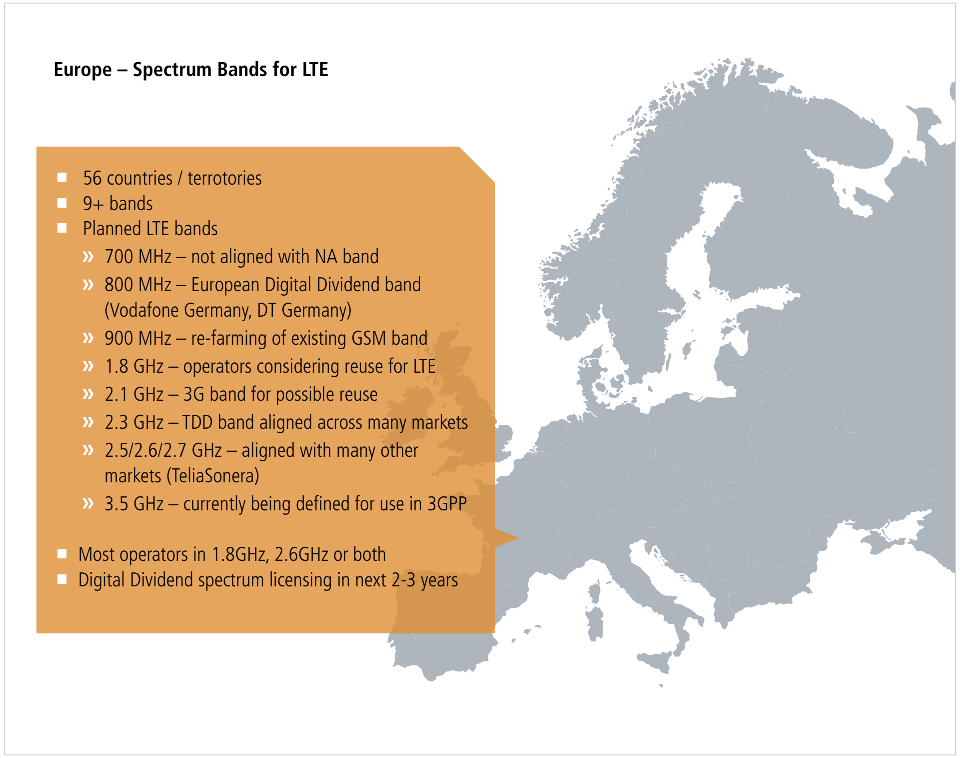
Figure 42: Network Technologies as a % of Regional Connections
Source: Wireless Intelligence

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

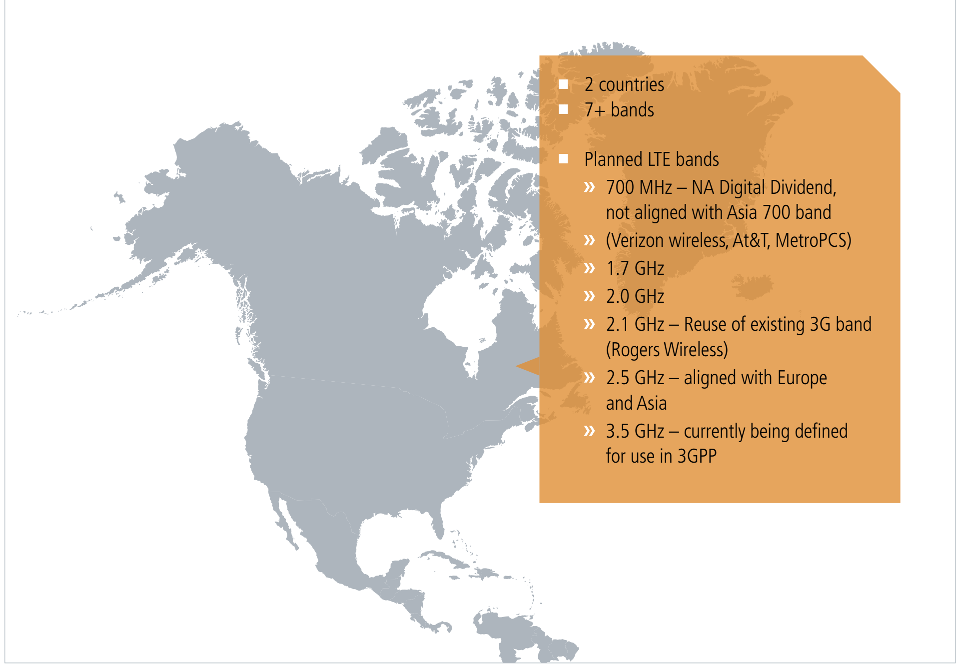
Regional Deployment Plans for LTE

The following slides show the availability of spectrum for LTE in different regions of the world.

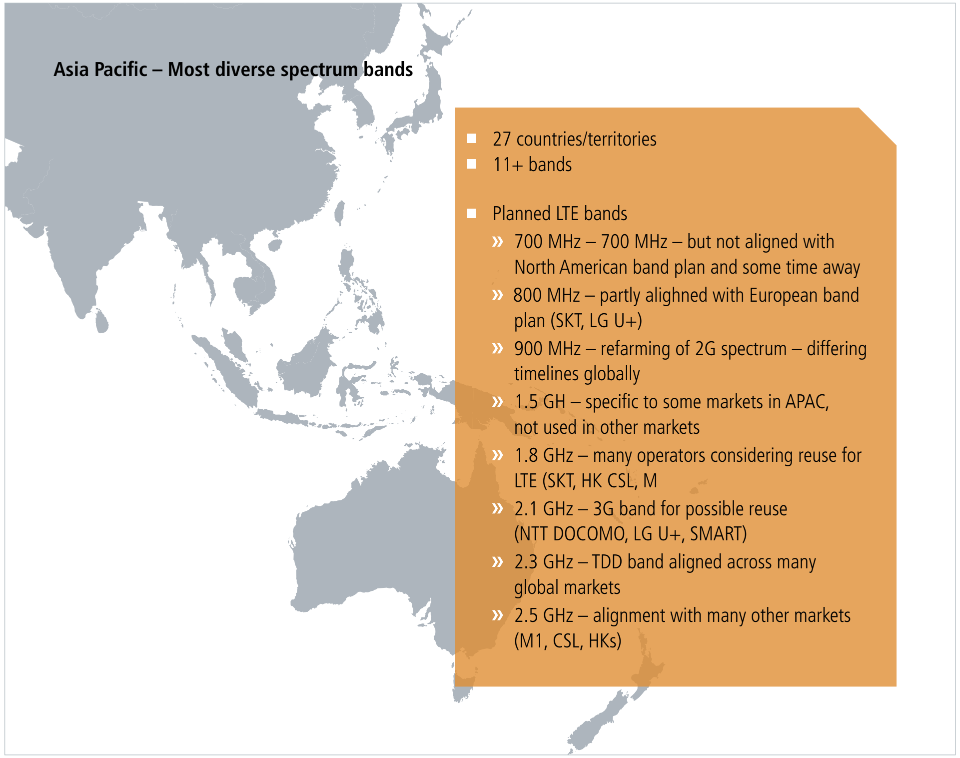


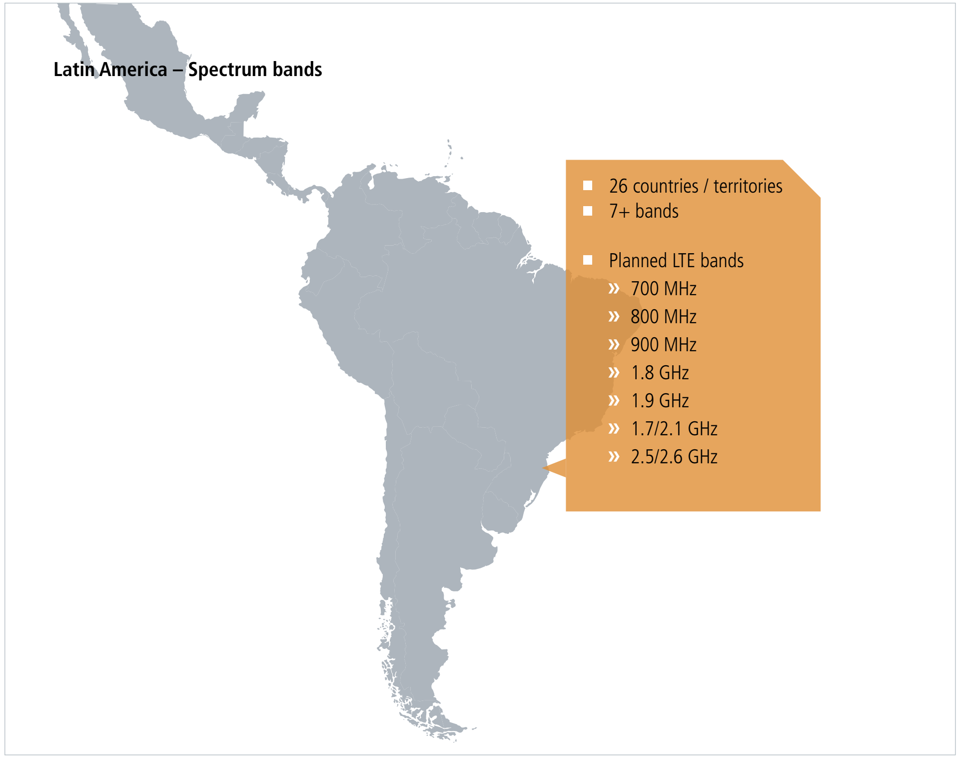


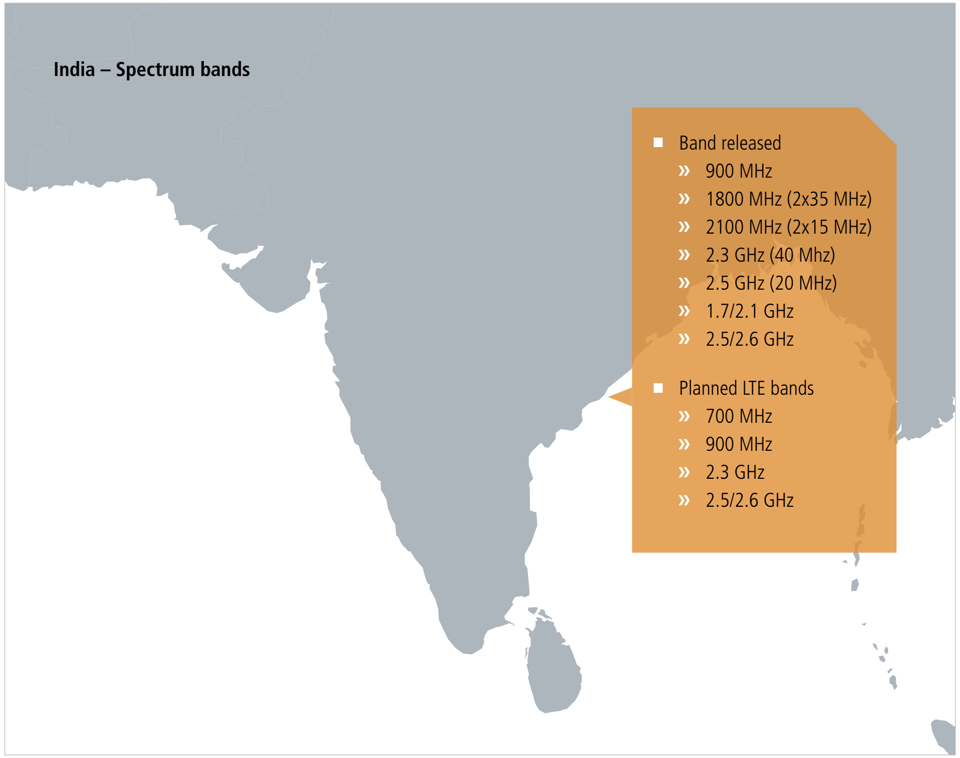
North America – Spectrum Bands for LTE



Asia Pacific – Most diverse spectrum bands




Latin America – Spectrum bands
26 countries / territories
7+ bands
Planned LTE bands
700 MHz
800 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

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About the GSMA and the Connected Living programme

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. Connected Living is a three year market development initiative whose mission is to help mobile operators accelerate the delivery of new connected devices and services. Our target is to assist in the creation of 700 million new mobile connections, whilst stimulating a number of service trials and launches in the Automotive, Education and Healthcare sectors. We also have a special focus on Smart Cities to support Barcelona becoming the Mobile World Capital.

About GSMA Connected Car Forum

The GSMA Connected Car Forum (CCF). launched in 2011, has successfully established a new platform for automakers and mobile operators to share information and enable joint industry cooperation to resolve barriers to connected car deployment and to improve the speed and take up of telematics and infotainment services.

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