

# A guide to 5G network security

Conceptualizing security in mobile  
communication networks – how does 5G fit in?



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# Executive Summary

## An introduction to telecom network security

- Today's telecommunication networks are generally separated into four logical parts: radio access network, core network, transport network and interconnect network. Each network part comprises three so-called planes, each of which is responsible for carrying a different type of traffic, namely: the control plane which carries the signaling traffic; the user plane which carries the payload (actual-) traffic; and the management plane which carries the administrative traffic. In terms of network security, all three planes can each be exposed to unique types of threats. There are also uniform threats which can affect all three planes simultaneously.
- Telecommunication network security is defined by the following components:
  - Standardization; a process whereby operators, vendors and other stakeholders set standards for how networks around the globe will work together. This also includes how best to protect networks and users against malicious actors.
  - Network design; network vendors design, develop and implement the agreed standards for functional network elements and systems, which play a crucial part in making the end network product both functional and secure.
  - Network configuration; at the deployment phase, networks are configured for a targeted security level, which is key to setting security parameters and further strengthening the security and resilience of the network.
  - Network deployment and operation; the operational processes which allow networks to function and deliver targeted levels of security are highly dependent on the deployment and operations of the network itself.

## In qualitative terms alone, 5G is worlds ahead of 4G

- From a user perspective, 5G is inherently different to any of the previous mobile generations. Machine-type communication, enabled by 5G, is widely anticipated to become the strategic difference and unique selling point of 5G in the long run. 5G networks will serve as critical infrastructures to facilitate the digitization, automation and connectivity to machines, robots and transport solutions etc. Thus, there is significant value at stake and, so too, a significantly different tolerance for risk.
- 5G marks the beginning of a new era of network security with the introduction of IMSI encryption. All traffic data which is sent over 5G radio network is encrypted, integrity protected and subject to mutual authentication e.g. device to network.
- Standardization authorities, such as those represented through 3GPP, do not standardize how functions are implemented and realized. The main purpose of the specifications is to secure interoperability between the functions required to provide network connectivity. Consequently, there is little about virtualization and cloud deployments in the specifications. These details will be addressed at the implementation and deployment phases.
- Fairly trivial malware is still prevalent for infecting devices or at least gaining an initial foothold within a targeted IT system. Simultaneously, telecommunication networks using specialized equipment can be targeted by malware which is anything but trivial.

## Understanding security in the era of 5G

Telecommunication networks are evolving rapidly across a broad technological environment which includes virtualization, IoT and Industry 4.0. This is met by an equally broad yet deteriorating cybersecurity environment.

Advances in technology, together with the broader development of networks beyond 5G RAN, are expected to have a significant impact on security, such as software-defined networking (SDN), network function virtualization (NFV) and edge computing. The 5G 3GPP standard is agnostic, in that it is flexible enough to allow for different types of physical and virtual overlap between the radio access network (RAN) and core network, for example, from a remote device to the Core network. The separation of functions between RAN and core raises questions about competitiveness and performance. From an economic, competitive and performance perspective, failing to make use of technological developments in the configuration and deployment of 5G commercial networks will ultimately prove counterproductive to realizing unique 5G use cases, such as critical machine-type communication or applications which belong to latency-sensitive autonomous systems.

In the era of 5G, it's important that, when we begin to conceptualize security on a system wide level where telecom networks are an important component, we adopt a strong understanding of the following:

- Increased value at stake and decreased risk tolerance
- Cyber-physical dependencies
- Security of standards, products, deployments and operations
- Proactive cybersecurity measures
- Vulnerability management
- Securing the supply chain.

# Contents

<b>1. Introduction</b>	<b>5</b>
<b>2. Conceptualizing security in telecom networks</b>	<b>7</b>
2.1 What is a telecom network and how does it work?	7
2.2 Key security consideration in the standardization, development, deployment and operations of telecom networks	7
2.3 What kind of threats do telecom networks meet?	8
<b>3. Critical Infrastructure - value at stake in 5G</b>	<b>9</b>
3.1 Key technology trends shaping the evolution of telecom networks	10
<b>4. 3GPP standardization of the 5G system</b>	<b>11</b>
4.1 What is a 3GPP standardized 5G system?	11
4.2 Security functions provided by the 3GPP standard	11
4.2.1 Mutual authentications	11
4.2.2 Confidentiality of user plane data	11
4.2.3 Privacy	12
4.2.4 Encryption and integrity protectionw	12
4.2.5 A false base station <sup>15w</sup>	12
4.2.6 Compartmentalizationw	12
4.2.7 Implementation aspects of the 5G system	12
4.3 Security Assurance in 3GPP SECAM	12
<b>5. Security Architecture in 5G</b>	<b>13</b>
5.1 System-wide security	13
5.2 Deployment/Vertical security	14
<b>6. Ericsson's 5G product security</b>	<b>15</b>
6.1 Key 5G security functionality	15
6.2 Ericsson's Security Reliability Model	15
6.6.1 Functions	15
6.6.2 Assurance	16
6.6.3 Documentation	16
6.6.4 Enabling Product Near Security Services	16
6.3 Avoiding vulnerabilities	16
6.4 Detecting flaws	17
6.5 Vulnerability watch	17
6.6 Vulnerability remediation	17
6.7 Ericsson's Product Security Incident Response Team	17
<b>References</b>	<b>18</b>
<b>Glossary</b>	<b>19-20</b>



# 1. Introduction

New forms of wireless connectivity are galvanizing a wave of digital transformation which is disrupting our industries and forcing us to rethink traditional ways of working. This transformation is not just changing how we work with IT, office tools and administrative systems; but it's also creating new business opportunities. Value chains are becoming value networks, where one-to-one relations between suppliers, vendors, operators and end-users are being reinvented as ecosystems of partners and co-creators.

## Internet of Things and Industry 4.0

This cross-industry transformation has created a need to evolve the concept of wireless connectivity for the fifth generation of mobile technology (5G)<sup>1</sup>, to enable new ways of defining performance monitoring and assurance as well as quality of service and user experience<sup>2</sup>. Compared with previous generations of wireless communications technology, the rationale for 5G development is to expand the broadband capability of mobile networks to provide specific capabilities not only for consumers but also for various industries and society at large. Hence, unleashing the potential of the Internet of Things<sup>3</sup> (IoT).

With IoT and Industry 4.0, a plethora of new device types with less homogeneity than today's PCs and smartphones will be connected with new and broader sets of applications. Not just internet-based apps and content, but rather real time, mission-critical, industrial control systems (Supervisory Control and Data Acquisition, -SCADA) systems. The next digital era will not just be confined to data behind screens and keyboards, but will also enter the cyber-physical domain through robots, sensors, and autonomous cyber-physical processes.

Digital transformation will further introduce new dimensions of attack vectors, values, and vulnerabilities through these connected digital systems. IoT brings a

new set of issues, such as the security, safety, and robustness of cyber-physical systems. Novel types of attack, as well as new privacy and cybersecurity regulations, may take many industries by surprise.

## Mitigating security and privacy threats under 5G

The subject of security and privacy continues to provoke a passionate response and high expectations from citizens and governments alike. At the same time, information security is a top concern among enterprises which are embarking on a digital transformation journey. It's imperative, therefore, that IoT is secure from the start, protecting personal data, business-sensitive information, and critical infrastructure.

Regulators are expected to walk a fine line between protecting privacy, safeguarding national security, stimulating economic growth, and benefiting society as a whole. To succeed with 5G transformation, industries need to gather competence, understand new threats and learn how to mitigate them.

Building a secure 5G requires us to take a holistic view and not only focus on individual technical parts in isolation. For example, interactions between user authentication, traffic encryption, mobility, overload situations, and network resilience aspects need to be considered together. It is also important to understand relevant risks and how to address them appropriately.

## 5G and end-to-end encryption

Adopting this broader perspective ultimately leads us to encryption, something which is often mentioned in public debate. End-to-end encryption, although an integral tool, is still just one of the many tools needed to ensure the security of a system. Let's not forget also, the trustworthiness of 5G does not only originate from a set of technical security features, but also from system design

principles, implementation considerations and the day to day operations of networks.

In this document, 5G refers to the entire ecosystem of IoT, Industry 4.0, cloud, internet services, digitalization and supporting technology in general. Telecommunication networks, both fixed and mobile, are set to play an important role in the 5G era, ultimately providing the necessary low-latency connectivity to the internet.

It should be clear however, that telecommunication networks do not provide end-to-end connectivity for all services. More specifically, mass-market IoT devices will only rely on telecommunication networks to obtain access to the internet. Devices like these are still required to have an over the top identity management scheme, end-to-end security solutions (between the device and the server on the internet) and must ensure their own specific application security.

Devices and applications which do not need to connect to the internet, such as a call between two mobile phones, whereby their communication will never leave the telecommunication network, enjoy comprehensive network security.

The mobile network parts and, to some degree, fixed access of telecommunication networks are specified by the 3GPP standardization organization. This document refers to these parts as the 5G system (see chapter 4), not to be confused with the more general use of the term 5G.



## 2. Conceptualizing security in telecom networks

### 2.1 What is a telecom network and how does it work?

Telecommunication networks consist of four main logical network parts: radio access network, core network, transport network, and interconnect network.

The radio access network (RAN) is an instance of access network, and a major part of modern telecommunications. There are many types of access networks, such as the 3GPP access networks: GSM/GPRS, UMTS, EUTRAN, NG-RAN (5G), satellite, and non-3GPP access networks: WiFi or fixed (wired) access network.

The core network can provide a number of services to subscribers that are connected via the access network into the core, such as telephone calls and data connections. The transport network keeps the access network connected with the core, and the base stations within the radio access network connected with each other. The interconnect network connects different core networks with each other. Telecommunication networks transfer voice and data across the globe with high quality and consistency. User devices such as mobile phones can stay connected regardless of time and place, which is all possible thanks to standardized signaling systems and interfaces.

Each network part can be subdivided further into three so-called network

planes, each of which carries a different class of traffic: signaling traffic, user payload traffic and management traffic. The signaling plane transports messages that are used to control user sessions, e.g. establishing a call or data session. The contents of a call or web page is referred to as user plane or user payload. The management plane includes management of monitoring, troubleshooting, configuration and optimization of networks.

All planes are of interest for threat actors for varying reasons:

- Signaling<sup>5</sup> – the metadata which supports the networks is targeted to obtain information such as the geographical position of a subscriber. Modification of signaling traffic may be attempted to re-route calls or intercept SMS messages of a target for eavesdropping purposes or denying service. Today's security risks are far more developed and complex compared to previous generation technology. As such, signaling of previous generations, such as 2G, was developed with a reduced focus on security. This was owing, in part, to a high level of trust in signaling peers. Now we know better. Telecom signaling is regularly attacked and sometimes exploited on a daily basis. In current 5G 3GPP standardization, security is now taking a central role across all aspects.

- User payload traffic contains the actual data that is transferred for the user. Without appropriate security measures, the privacy of the user and the confidentiality of enterprise or government data would be at risk. So far, integrity protection for user payload traffic has been seen as necessary.
- The management layer is needed to ensure that the service provider's business performs optimally. The management plane is an attractive target for hackers to gain access to network resources, where they can manipulate and disturb network traffic and data. Mitigation of network management related risks and threats requires security policies and several security controls to be implemented, such as access control and security monitoring, in the right places (section 4).

### 2.2 Key security consideration in the standardization, development, deployment and operations of telecom networks

Standardization has played a vital role from the beginning of the emergence of global cellular networks such as GSM or 2G. In this process, operators and vendors agree about how networks around the globe will work together and how the networks and users can be protected against malicious actors. Network vendors translate the agreed standards to functional network elements and systems. The design and development performed by the network vendor is a crucial part in making the end network product functional as well as secure.

In the deployment phase, networks are also designed and configured for targeted security level, as well as to set security parameters and further harden the resilience of the network. At the operational phase, operational processes which facilitate the network and deliver a targeted level of security are highly dependent on the deployment and operations of the network. One way of

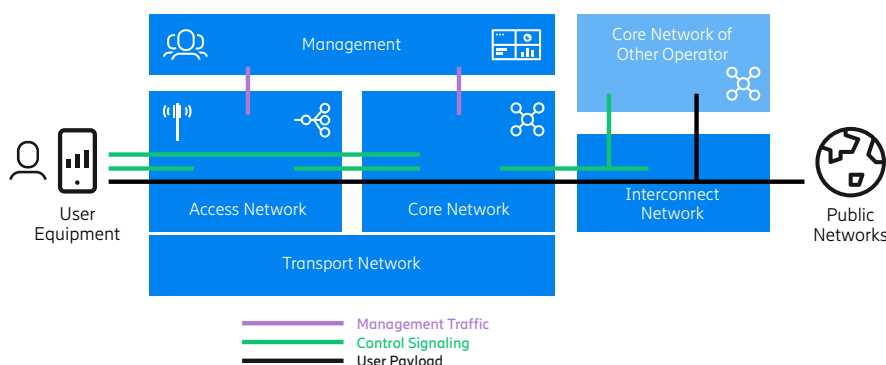


Figure 1: The mobile communication network – logical elements and logical planes

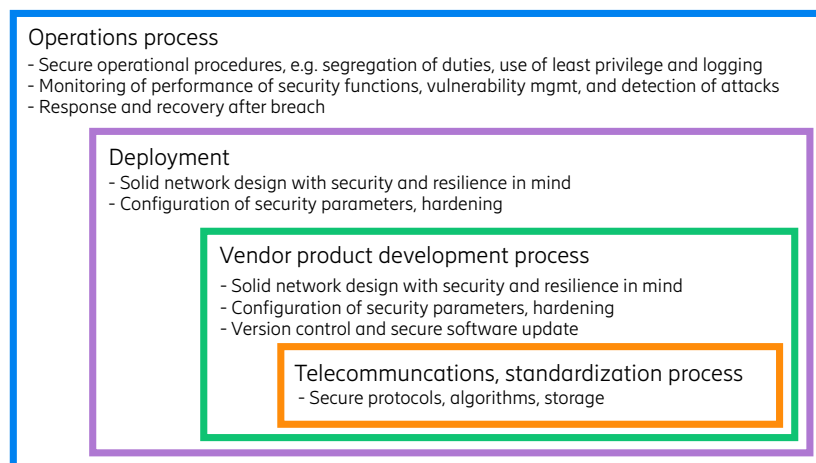


Figure 2: Key security considerations

depicting these four interrelated processes is shown in figure 2.

While the fundamental security features are specified in standardization, vendors enjoy a lot of room to maneuver throughout the development process, and so too operators throughout the deployment and operation processes.

Vendors implement common technologies differently<sup>7</sup>. Main features like interoperability and roaming are necessary, while non-common features (e.g. value adding features) differ from vendor to vendor. The quality and security of vendors' implementations vary and competition between vendors is an important driver for product level security.

A high level of product security assurance is vital for success in security. Security assurance, an important process in the vendor's software development process, usually contains a set of sub-processes on different levels to ensure that a product functions and performs as it is intended, and nothing else. Vulnerability assessment and penetration testing or risk assessment and privacy impact assessments are examples of such sub-processes. In addition, every piece of code needs to be reviewed and scanned for flaws and vulnerabilities. Security assurance is not limited to internal activities only.

Supply chain security controls often form a crucial part of a vendor's security activities. Similar standards of internal security need to be extended to suppliers of components and third-party software used in the end products and solutions. Most of the vulnerabilities exploited in live networks are publicly known vulnerabili-

ties, often present in commonly used software components. Therefore, extra attention must be paid to monitor and respond to any vulnerabilities in any third party components which are used.

### 2.3 What kind of threats do telecom networks meet?

Cybersecurity threats facing societies and industries have largely remained the same for the past ten years. Fairly trivial malware is still the prevalent way of infecting a device or for gaining an initial foothold within a targeted IT system. Simultaneously, telecom networks using specialized equipment can be targeted by malware which can be anything but trivial. Aside from the variation and sophistication of technical threats, the mode of operation of attackers and the cyber-threat landscape has shifted considerably over time.

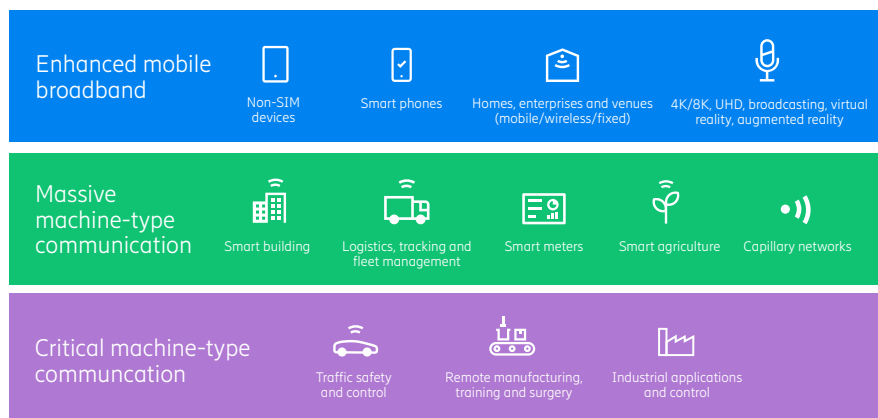
Crime-ware (attack toolkits) is currently being sold as-a-service, complemented with options like trial periods, 24/7 user support, dedicated discussion forums and multi-language documentation. This development has contributed to a dramatic increase in the frequency of cybersecurity attacks, in combination with attractive incentives (i.e. cyber-attacks constitute a low-risk high-pay-off crime). Due to high degrees of digitization of industries and public services, the increased frequency of attacks has also been aggravated by increased severity of impact that a cybersecurity attack can result in. Collectively, this is why cybersecurity has become a top concern and a boardroom level discussion worldwide.

The threat actors behind cyber-attacks and their methods vary. When money is at play, the interest is high from criminals – deriving predominantly from malicious external actors, but so too internal actors from within the network operators' or IT system organization (e.g. employees or subcontractors). For instance, having access to the billing and charging system of a telecom network allows insiders with malicious intent to commit fraud. Other typical attacker groups are hacktivists – politically motivated saboteurs who intend to disrupt service, deface websites or steal sensitive information with the intent to cause financial damage or to send political messages. Another common class of attackers are insider threats such as disgruntled former employees or employees who seek to exploit their trusted position for personal gain.

While the same groups that target any other industry also attack operators, telecommunication networks have some unique characteristics that makes them an interesting target for nation-state actors and espionage. Telecommunication networks store and transfer location data and sensitive information like messages and voice conversations between high value targets, e.g. government officials, decision makers and high-ranking leaders. The target data can contain information such as who has said what, when and to whom. Such information is of high interest to intelligence organizations from different parts of the world.

Industrial espionage has moved into the digital sphere as more and more of the valuable assets a company has, are created, stored and shared digitally. The goal is to gain access to a company's trade secrets like financial records, pricing information, intellectual property like new technology/innovations, and sensitive customer information. The uniting factor is the actor's objective of using information to swing the competitive situation in their favor. State actors (or state supported actors) have always had an interest in keeping an eye on what other states are doing. As social, economic and political activities have increasingly moved to the digital space carried over public telecom networks, intelligence gathering operations have followed suit.

### 3. Critical Infrastructure - value at stake in 5G



**Figure 3:** 5G Use cases- two types of machine type communication

5G will expand traditional relationships between consumers, business users and mobile network operators. The expansion will include new relationships in the form of digitized and automated business processes of enterprises, control and operations of machinery of industry companies. Furthermore, cyber-physical interdependency between telecommunication networks and smart connectivity of other infrastructure providers (cities, power, utility, transport etc.) will be enabled by new ways to access the mobile network. Ultimately this extension in relationships will depend on trust between different stakeholders.

The 5G use cases for massive and critical machine-type communication (figure 3) are embodiments of new types of payload carried over mobile networks. Although mobile broadband has been available and on the market for quite some time (mobile broadband was introduced in 3G), 5G is widely expected to introduce new qualitative and quantitative improvements, such as higher data rates, faster response times<sup>8</sup> (in the form of lower latency), more devices that can simultaneously connect to a base station and higher bandwidth, across a wider area of geographical coverage. Furthermore, 5G also provides an increased level of security relative to 4G (see section 5).

The massive machine-type communication (which is a 3GPP term for IoT) will support tens of billions of power-constrained devices which typically transmit at irregular intervals, low volumes of data

that are insensitive to delay.

Most industry stakeholders foresee a huge amount of relatively simple devices that will need connectivity, and create valuable data sets. For example, in the case of an intelligent door lock, compromising the confidentiality and/or integrity of a single door lock is a simple hack. Compromising the confidentiality of a million door locks is an intelligence operation.

For applications which rely on 5G critical machine-type communication, they'll enjoy the benefit of ultra-reliable and low latency connectivity, where data volumes can be high and business critical. In this case, the communicating end-points are intelligent machines, vehicles and robots with or without human interventions i.e. autonomous<sup>9</sup>.

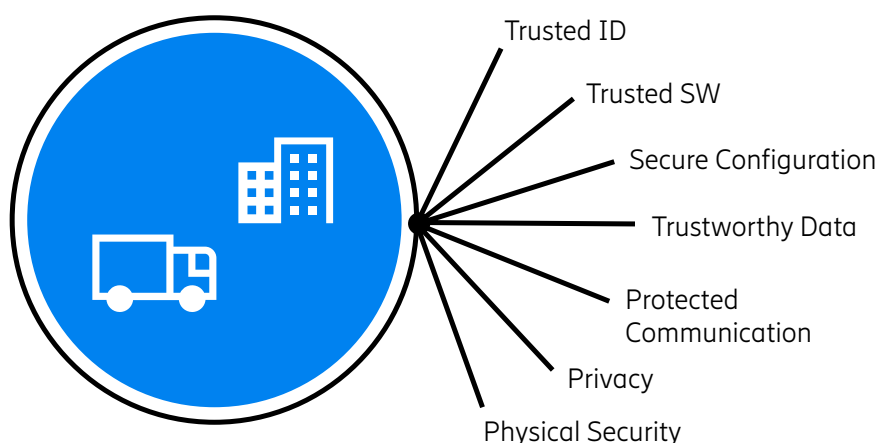
Industries and services which are expected to leverage such connectivity are: healthcare, manufacturing, transport and consumer goods.

While IoT is a phenomenon that has already arrived, and can even be leveraged using both 4G and non-3GPP access technologies, the machine type communication cases in 5G networks will empower IoT with network capabilities such as ultra-low latency which has not yet been available.

From a 3GPP network perspective, IoT means that mobile networks no longer connect only human identities in the form of consumers and business users, but also device identities. To achieve the necessary level of targeted security in mobile networks, the trustworthiness of connected IoT devices must be considered which, at the very least, entails assuring the IoT device's identity and access control, in essence access privileges and confidentiality of associated data generated by the IoT device (see figure 4).

From the 5G network point of view, trust in IoT is based on trustworthiness of the device's hardware, software, configuration etc. Hence, trustworthiness is cumulative and will be defined by how well network operators and those who manage IoT devices govern the following:

- identities and data,
- security and privacy,
- actor compliance with agreed security policies end-to-end.



**Figure 4:** IoT device security aspects



## Network slicing

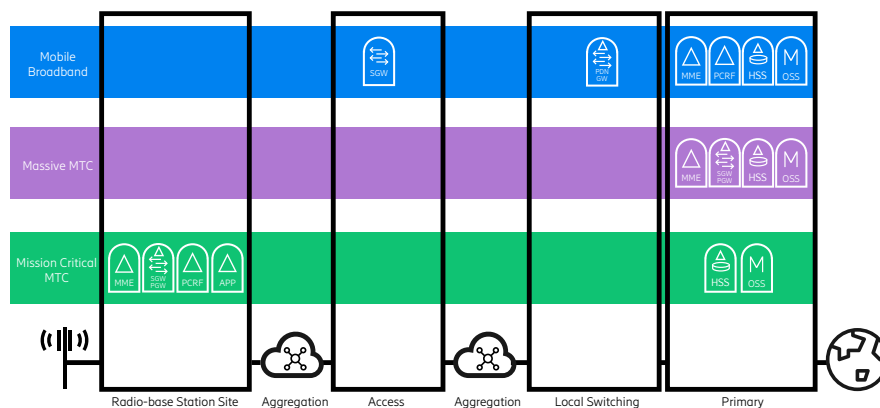


Figure 6: Network slicing

From a connected IoT device point of view, the level of trust between actors and identities depends on the existence, efficiency, and transparency of trust enablers, such as trusted hardware and software, trustworthy identities, communication, data and privacy, and trusted operations.

Trustworthiness also depends on the right combination of trust enablers. For example, the hardware-based trust does not help if the application on top of the hardware does not make use of it. Ultimately, fully trusted application does not help, if the communication, e.g. the network between the applications cannot be trusted.

### 3.1 Key technology trends shaping the evolution of telecom networks

The 5G system may only appear as a faster and more versatile radio technology but it is much more. 5G is the first generation that was designed with virtualization and cloud-based technology in mind. The 5G system is not static for any specific access type or radio technology. For example, new services provided by the 5G core network are also available via 4G radio, WiFi or fixed access depending on the network configuration. Evolution towards the 5G system had started in the mid-2000s when the focus in telecommunication networks was shifted from circuit switched telephony services to packet switched networks and mobile broadband (figure 5).

With cloud-based technologies, software execution can now be disconnected from specific physical hardware (removing the need for boxed, e.g. hardware dependent functions). This is made possible thanks to Software Defined Networking (SDN) and Network Function Virtualization (NFV). SDN offers flexibility how to configure the routing paths

between dynamically configured virtualized network functions. The introduction of AI and increasingly powerful computers, together with cloud technologies, will become a key driver of automation technologies. Consequently, the dominant tendency in these technology trends is already resulting in telecom networks becoming more and more software driven.

Distributed cloud computing makes it possible to create partitioning for better resilience and latency. From a security perspective, the distributed cloud may introduce new attack vectors against the 5G network if security is not built-in. On the other hand, distributed cloud may be seen as an opportunity, because of the possibility to place security functionality and mitigation mechanisms close to the attack a source and thereby isolating the scope of the attack to local area.

The trend of connectivity, machine learning and other forms of AI is becoming more and more integrated across applications. Furthermore, market movement toward automation and autonomously

controlled devices and vehicles is already beginning to take place at scale. Consequently, when these movements intersect, intelligent and autonomous devices will be an integral part of industry and society.

How all these technologies are built, integrated and controlled will become a major trust management issue for the future, particularly for usage in critical infrastructures and to ensure privacy is protected. Here, the trust dimension is crucial with the need for suppliers and operators to independently manage trust and have outstanding capabilities to do so.

Network slicing<sup>13</sup> (see figure 6) is about separating different types of user traffic and creating dedicated core networks ad-hoc to facilitate a whole range of different 5G use cases (see figure 3). Network slicing enables the creation of device type, industry sector or even customer specific subnetworks. The network slice control mechanism needs to provide appropriate slice management, configuration of access control, and secure isolation while still authorizing the shared resources. Each slice may have its own security policy that defines the security controls applicable for its specific threat landscape.

Network slices designed for critical services may also use the shared resources but require careful isolation. Critical services require high reliability, resiliency, safety, security and, often also, privacy. The security of critical services must ensure that communication parties and the connections remain protected. This requires comprehensive security approach including automated asset management and verification of security policy compliance.

## The evolution towards 5G

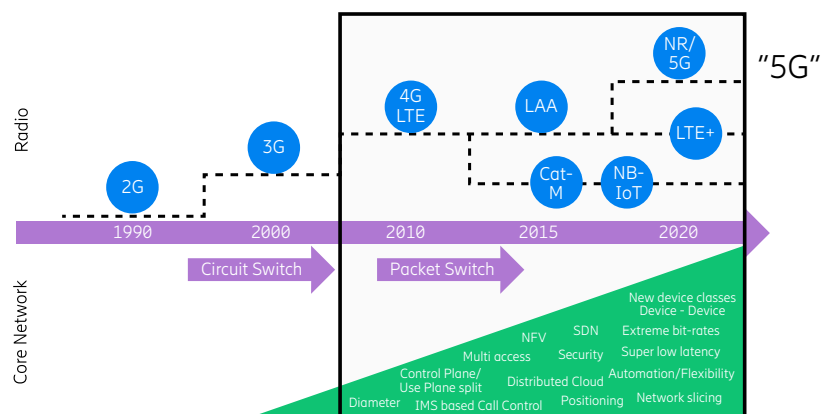


Figure 5: Evolution toward 5G and key technology trends

## 4. 3GPP standardization of the 5G system

### 4.1 What is a 3GPP standardized 5G system?

The main service which the 5G system provides today's users is mobile (wireless) connectivity of a device to a network, often for Internet connectivity. This is also why the first 5G system use cases e.g. enhanced mobile broadband and fixed wireless access, were piloted to offer users a better experience of the Internet.

3GPP does not typically standardize application services (such as Internet applications) since they are considered to be out of scope of 3GPP's connectivity focus. There are however a few exceptions: telecommunication networks have traditionally provided the possibility for two devices to connect to each other with the support of the network (e.g., to set up voice calls). In 4G networks, voice calls are set-up using voice over LTE (VoLTE) service on top of the connectivity service. VoLTE uses the IP Multimedia Subsystem (IMS) also standardized in 3GPP, similar voice service is also planned for 5G. Furthermore, 3GPP standardizes the security to support these services.

3GPP standards also cover some aspects of machine type communications and IoT. Here, the focus is to provide the devices with connectivity. Consequently, the 3GPP standards cover efficient means to provide these devices with an IP point of presence. Any security issues related to the actual application is considered out of scope and needs to be taken care of over the top. For example, 3GPP's 5G system can provide a temperature controller in a refrigerated goods wagon of a train with IP connectivity, but seen from the general 5G view, the authentication of the management traffic to the controller must be addressed over the top, since the IP address may be accessible via the Internet, so anyone could send messages to the controller.

Apart from the security assurance specifications (see section 4.3 below),

3GPP does not standardize how 5G system functions are implemented and realized.

The main purpose of the specifications is secure interoperability between the functions required to provide network connectivity. Consequently, there is little about virtualization and cloud deployments in the 3GPP specifications. Those aspects are handled by other standards organizations, especially ETSI ISG NFV (European Telecommunications Standards Institute, Industry Specification Group, Network Functions Virtualization) and ONAP (Open Network Automation Platform). Some details are not standardized at all and are left for implementations and deployments. Further, aspects that are part of a digitized society and industrial IoT that are not related to the radio access connectivity is mainly out of scope for 3GPP.

### 4.2 Security functions provided by the 3GPP standard

This section contains an overview of some of the most important security services provided by 3GPP standard to safeguard the connectivity for users, and the service availability and charging by the operator of the network. 3GPP's 5G system standards provide security mechanisms, which are based on well-proven 4G security mechanisms, but also include new enhancements for e.g. encryption, authentication and user privacy.

While 3GPP security mechanisms provide reliable links for non-malicious bad radio conditions (see below) they do not protect against all possible threats, for instance DDoS and radio jamming. Protecting against DDoS attacks and radio jamming is something that is left for implementation and deployment, e.g. to re-route traffic via other base stations if one is jammed, or scaling mechanisms and selective dropping/throttling in case of DDoS. Therefore, the appropriate level of cyber-resilience in the 5G system and 5G in general needs to be understood and

addressed in a much broader way (see section 5) – 5G standards or, for that matter, any other technical standards will only be part of a much bigger picture.

**4.2.1 Mutual authentication:** the end-users of the 5G system are authenticated to support charging for network access, accountability (e.g., which user had which IP address and when), and Lawful Intercept. The network is also authenticated towards the end-users so that the end-users know that they are connected to a legitimate network.

**4.2.2 Confidentiality of user plane data** – the actual traffic data that is being transmitted – is achieved by encryption of end-user data as it passes through the mobile network to prevent eavesdropping over the air or on wires. Once the data leaves the 5G system and traverses the Internet, the 3GPP standard does not ensure confidentiality.

**4.2.3 Privacy** threats to end users are mitigated by mechanisms that protect user identifiers. Note that, similarly to confidentiality, even though the 5G system protects the privacy of the end-user using an Internet application over the 5G system, the 3GPP standards do not intend to, and cannot, mitigate all privacy threats outside the 5G system even though there may be privacy concerns for the application also in a more general 5G setting. These threats require additional efforts by Internet application providers. The 5G system protects the messages sent by a social media user while they traverse through the mobile RAN and 5G system core network. The social media service must itself ensure that the message is protected end-to-end, since it will traverse the Internet once it leaves the 5G system. It is of course also up to the social media service to ensure the privacy of the user data once it has reached their servers and is being stored and processed.



#### 4.2.4 Encryption and integrity protection

3GPP standards ensure that appropriate encryption and integrity protection algorithm choices are made. 3GPP here enjoys the support of security algorithm expert group of ETSI (European Telecommunications Standards Institute), specifically ETSI SAGE (Security Algorithms Group of Experts). For IP layer and above, 3GPP relies on well-proven IETF security protocols.

The 5G system provide reliability and robustness against non-malicious unavailability situations, i.e. errors that appear due to unusual but expected bad radio conditions and broken links.

**4.2.5 A false base station<sup>15</sup>** in GSM could identify a subscriber via the IMSI (International Mobile Subscriber Identity)<sup>16</sup>. The technique is called IMSI catching. In GSM an attacker could even eavesdrop on users' data. Later generation mobile networks, starting from 3G, prevent the eavesdropping attacks because the network is there authenticated to the user. However, IMSI catching attacks are still possible in 3G and 4G. In 5G standards, even IMSI catching attacks are prevented. This is through a technique where the user's long-term identifier is never transmitted over the radio interface in clear text. Further, 5G increases the frequency with which temporary user identifiers are updated, further improving privacy.

**4.2.6 Compartmentalization:** The 5G system supports different types of compartmentalization, e.g. functions that aim to isolate possible security breaches from escalating from one part of the network to another. For example, there is a clear split between the Radio Access Network and the core network functions. This means that, should a radio base station get compromised, the core network, which provides global functions and processes more sensitive data, is still

secure. Other examples of compartmentalization are cryptographically separated keys used at mobility events, and network slicing. Isolation of network slices is an important aspect, but it is not in the scope of 3GPP standards and is provided through implementation and deployment, e.g. targeted for specific use cases (see section 3) and desired performance and derived economic benefit.

Finally, one of the key purposes of 3GPP standardization is to ensure interoperability of security mechanisms between 5G system functions.

#### 4.2.7 Implementation aspects of the 5G system are only standardized by 3GPP to a very limited degree.

For example, whether certain functions are implemented in single physical servers (physically isolated and separated) or implemented as virtual machines (VMs) in a cloud or virtualized environment (shared hardware) is up to implementation and operator deployment choices (economics). This means that there is no simple rule of thumb derived from 3GPP standards regarding the separation of RAN and Core functions but rather flexibility prevails, even in a single physical network different configuration for different 5G use cases are possible, resulting in several differently configured logical networks are running over one physical network. For functions implemented in a traditional non-virtualized fashion, 3GPP, in cooperation with GSMA, develops security assurance specifications, which sets requirements for some implementation aspects<sup>17</sup>.

**4.3 Security Assurance in 3GPP SECAM** Mobile networks form the backbone of the connected society and are even classified as critical infrastructure in some jurisdictions, making security assurance especially important. Early on, the telecom industry realized the need to ensure secure implementations in addition to the

secure standardized system and protocols. Therefore, 3GPP and GSMA took the initiative to create a security assurance scheme called the Network Equipment Security Assurance Scheme (NESAS), which is suitable to the telecom equipment lifecycle. Ericsson strongly and actively supports the initiative in both 3GPP and GSMA by feeding the strongest parts of our own Security Reliability Model (SRM) into the scheme, ensuring the other parts are covered by the scheme, and aligning the two.

NESAS comprises two main components: security requirements and an auditing infrastructure. The security requirements are defined jointly by operators and vendors in 3GPP. These requirements are currently defined on a node basis and collected in so-called SeCurity Assurance Specifications (SCAS). There is, for example, one specification defining security requirements for 4G base stations. Various types of requirements exist, including the use of functional security policies, such as minimum length of management passwords, but also qualitative requirements on hardening and penetration testing. The auditing infrastructure is governed by the GSMA, the global mobile operator organization. The GSMA appoints audit firms that perform the audits of vendors' development and testing processes. The GSMA also awards certificates to the vendors that pass audit and revokes certificates from the ones that do not.

NESAS aims to meet the needs of many national and international cybersecurity regulations, such as the EU cybersecurity certification framework. The move towards larger portions of products being software – as we can see with SBA and cloud-based implementations – also offers the possibility for faster update cycles if vulnerabilities are discovered.

## 5. Security Architecture in 5G

The 3GPP standardization section (4) focused on security mechanisms in scope for 3GPP, that being the functional elements and interfaces. Additional security considerations related to deployment scenarios of 5G system are covered in this section, including:

- System-wide security (horizontal security)
  - Network level
  - Slicing
  - Application level security
  - Confidentiality and integrity protection
  - Interconnect (SBA)
- 5G function element deployments (vertical security)
  - NFV
  - Distributed clouds

### 5.1 System-wide security

As noted earlier, consumers and enterprises use existing (4G/3G/2G) cellular networks for mobile broadband (connectivity services), messaging service (e.g., SMS), and telephony services. Societal behavior and business services are evolving which raises the expectation on cellular networks to provide reliable and secure communication.

The aim of 5G is to become a reliable and trusted innovation platform for businesses and organizations to build and deliver new added-value services, but it is also considered an enabler for digitizing and modernizing critical national infrastructures such as energy, transport etc. The latter raises the bar for 5G systems to provide greater availability and improved assurances of secure communication services. The horizontal, system-wide security approach spans across the network from the user device to the reference point where the operator terminates their services.

Horizontal security (see figure 7) is achieved by combining and coordinating a multitude of security controls across

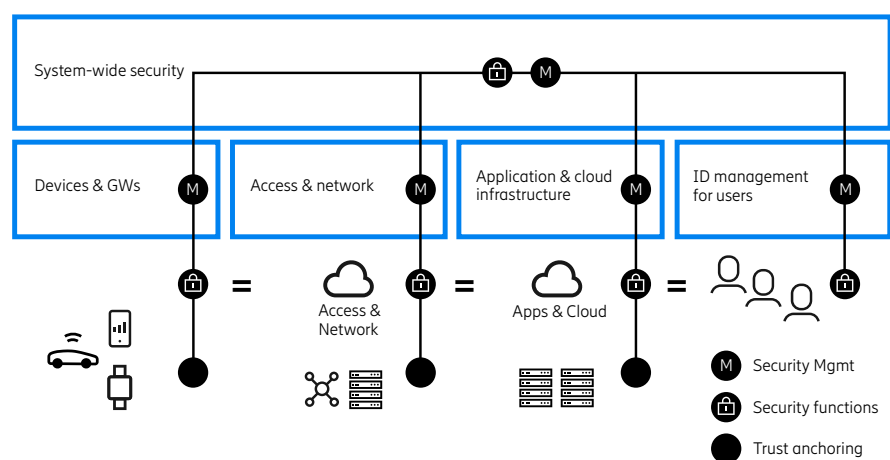


Figure 7: System-wide security

different domains in telecommunication networks, including radio access (e.g., radio unit, baseband units, antennas), transport networks (e.g., optical equipment, Ethernet bridges, IP/MPLS routers, SDN controller), packet core (e.g., MME, S-GW, PGW, HSS), network support services (e.g., DNS, DHCP), cloud infrastructure, and various management systems (e.g., network management, customer experience management, security management). Security across all these domains must be coordinated to provide the targeted availability of services and confidentiality and integrity of data sent, stored, and processed within the 5G system. Horizontal security will also protect the privacy of 5G users based on that data sent over the system is always confidentiality and integrity protected.

The previous section described the controls available in 3GPP nodes but let us now explore controls and design considerations in the transport and cloud domains in the 5G system.

Transport networks play an important role in the 5G system because they provide high speed low-latency connectivity services between all 5G network functions. Consequently, the availability of transport networks is directly related to the avail-

ability of the 5G system and the services it provides. To ensure availability of transport services during node failure, cable or fiber breaks, or overload events transport networks can employ various technical solutions as well as considerations during network design, including:

- Geo-redundant paths that allow traffic to be re-routed in case of a path failure.
- Link redundancy solutions for fast failover in case of port or link failure.
- Path redundancy mechanisms that re-routes traffic flows due to path failure or overload conditions.
- High-availability configuration of critical network nodes to handle node failure.
- Use of traffic segmentation mechanisms (e.g., VLAN and MPLS) to logically separate traffic between different domains.
- Quality of Service enforcement using traffic queuing mechanisms, rate limiting, and traffic policing for resource and congestion management.
- DDoS detection and mitigation solutions.
- Port-based authentication to verify authorized network devices are attached to the network.
- IPsec or MACsec to create authenticated and cryptographic secured tunnels for sending data between sites and network elements.



The Service Based Architecture (SBA) and splitting of functionality in the traditional radio baseband unit opens to deployments in cloud environments. This flexibility grants several opportunities to realize new value-added service offerings, but also bares new risks and attack vectors that must be controlled in order to uphold the operator's targeted security posture. Some activities and controls to increase the trustworthiness in cloud include, but are not limited to:

- Hardening of the Network Function Virtualization environment, e.g., host OS hardening, secure configuration of the hypervisor or container environment.
- Tenant separation such that tenants are unable to interfere, have unauthorized data access, or intercept network traffic from other tenants.
- Compliance monitoring of tenants to ensure they remain within defined security policy
- Generation of detailed audit trails to support incident response and restoration activities
- Workload life-cycle management to ensure secure onboarding of virtual network functions, verify the integrity of software during boot and the integrity of workloads in operations, and secure decommissioning of workloads.

A logical construct that is used to describe the segregation of network services with different performance and security properties is the network slice. Several of the abovementioned controls and design guidelines will be combined to realize different network slices. For instance, a mission critical application that requires high availability, priority access to resources, and isolation from other services may be realized using services with geographic path redundancy with fast failover, authenticated with confidentiality and integrity using IPsec, and processed by dedicated 5G Core network functions deployed on committed server

blades and network security functions deployed with policies tailored to the specific application requirements.

## 5.2 Deployment/Vertical security

3GPP specifies network functions and how they interact, but it does not specify how network functions should be implemented in embedded systems or in virtual environments.

Traditionally, radio base station equipment and radio core nodes are developed on vendor designed hardware platforms. These platforms have been carefully designed to meet strict requirements on availability, mean time between failures (MTBF), performance, scalability, power consumption, and physical security properties.

For example, a radio baseband unit includes tamper resistant hardware to securely store sensitive secrets, support secure boot procedures that verifies the integrity and origin of software that is loaded onto the hardware, and hardware accelerators to boost cryptographic performance. During the manufacturing of baseband units, the hardware is provisioned with vendor unique credentials, called Vendor Credentials, that are used to cryptographically authenticate the device vendor of origin. This credential is used to secure deployment and integration of baseband units into operator networks. These credentials are securely stored on hardware devices with an established Trusted Execution Environment (TEE) as specified by the Trusted Computing Group creating trust that can be carried into deployment that is rooted in the hardware.

In virtualized deployments, the situation is different since multiple vendors may be involved in providing different parts of the solution, such as the hardware infrastructure, the virtualization platform, and the applications execute the 3GPP network functions. Secure provisioning and storage of identifiers and credentials is integral to

provide a secure deployment in virtualized deployments. Currently, the industry is working on establishing methods to achieve similar trust and security as in embedded systems. For instance, hardware platforms (data center servers) need to include hardware technologies such as trusted platform modules (TPM), hardware security modules (HSM), and secure enclaves in CPUs and these capabilities need to be utilized by the virtualization platform and exposed to and attested by applications running on those platforms.

Virtualization of 3GPP functions allows a flexible distribution of the functions across infrastructure across the network in ways that are not possible for hardware-based solutions. It is possible, for example, to deploy a network slice where both RAN and Core Network functions deeper in the network towards the edge on distributed cloud platform to serve local enterprise services or regional IoT applications. This requires that network orchestrators which deploy the applications, the distributed cloud platform on which the applications run, and the applications themselves can be hardened and provide enough security controls. This is necessary to meet the operator's wanted security posture, at the same time as fulfilling the security requirement for the network slice use case. This is achieved by solutions that coordinate service deployment and security configuration across all involved domains. After deployment, continuous monitoring is needed to verify that the wanted security state is maintained throughout the lifecycle of deployed services.

## 6. Ericsson's 5G product security

Ericsson's 5G radio network products build further on proven 4G platforms which, today, offer state-of-the-art security functions such as support for secure protocols, e.g. TLS and IPsec, on all interfaces, vendor credentials, HW rooted trust anchors for trusted boot, and signed software to ensure that only software provided by Ericsson can execute on the platform.

Such functions together with others such as access management, logging, and analytic tools constitute a solid foundation for implementing security policies and operating the network securely. The SRM framework specifically addresses operational needs by mandating hardening guidelines and security user guides for all Ericsson products. Additionally, Ericsson strategically offers products near security engineering services to assist operators in making network security assessments and configuring the network according to identified needs.

### 6.1 Key 5G security functionality

In addition to the improvements already described as part of the 5G standards, new deployment scenarios and use cases drive the need for applying state-of-the-art security technology. Ericsson is actively working in several areas to achieve this.

A fundamental challenge instantiating a Virtualized Network Function (VNF) is to securely provision it with roots of trust that enable it to become a trustworthy peer in the network that can protect the confidentiality and integrity of data both in transit and at rest. Here, Ericsson have developed solutions, founded in in-house research and built directly into the 5G offering.

For Physical Network Functions (PNF), i.e. traditional HW/SW deployments, Ericsson's 5G offering inherits the hardware rooted security for secure boot and signed software verification established already for 4G/LTE.

5G functionality, when established in the market, will provide for many new use

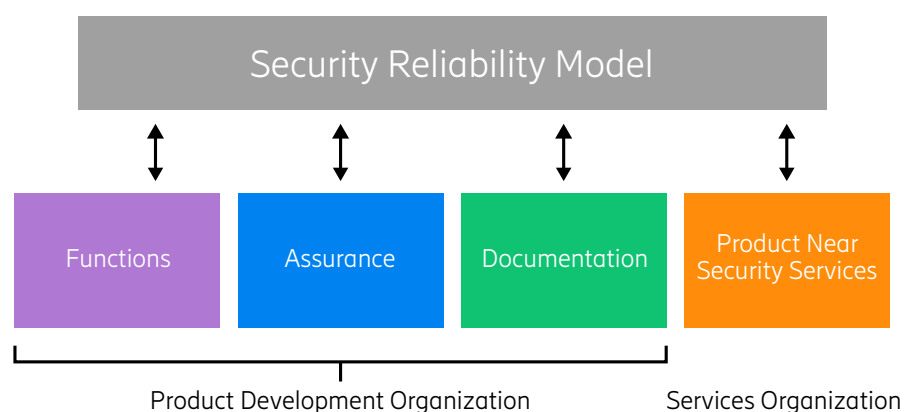


Figure 8: Security Reliability Model

cases and more actors interacting with the infrastructure. In this new environment, efficient control of who may interact with whom, and who may do what and where, becomes a central security objective. To this end, Ericsson is already developing tools for efficient and correct policy management, policy distribution, policy verification, and policy enforcement that can enable functionality across tomorrow's networks.

Defense in depth is an important principle and what cannot be prevented must be detected, responded to, and recovered from. Telecom networks are uniquely instrumented to monitor performance in general. Ericsson is leveraging and augmenting these capabilities and together with modern analytics technology, drawing upon AI and Machine Learning, creating intrusion detection capabilities for our networks.

One specific concern that has received considerable attention is the ability to build a false base station through readily deployable technology and at relatively low cost. In this area, Ericsson has contributed toward standardizing functionality that will make it possible to efficiently detect the presence of rogue radio nodes in the network.

Perhaps one of the most important

priorities for Ericsson is the relationship between usability and serviceability. Security functionality is of little value if it is not used or if it is used in ways that defeats its purpose. Here, Ericsson is working toward making security functionality unobtrusive and the default thing to do. Ericsson also engages with its customers to show and discuss how its products can be leveraged to contribute to reaching the customer's operational security objectives.

### 6.2 Ericsson's Security Reliability Model

For many years, Ericsson has worked systematically to incorporate security considerations into all phases of product development and has a well-established internal governance framework for product security, the Security Reliability Model (SRM) (see figure 8). SRM is how Ericsson is able to consistently deliver on security ambitions in products. Its key characteristics are that it:

- Defines the product security and privacy ambition level,
- Ensures the implementation of appropriate security and privacy,
- Follows up and measures actual product security and privacy status, and
- Enables Product Near Security Services. Ericsson's internal "Area of Regulation

(AoR): Product Security and Privacy” defines how responsibilities and authorities are distributed between different roles and functions to manage and control product security and privacy across Ericsson products. SRM is linked to the distinct responsibilities and defines in detail what needs to be implemented and which activities need to be performed.

SRM is enforced through the above “AoR Product Security and Privacy”, and further details are provided by a set of Ericsson internal Generic Product Requirements (GPR). GPR defines the key product functionalities, security and privacy related product documentation which are needed, as well as confirmation of security assurance activities.

#### 6.6.1 Functions

Security Reliability Model (SRM) defines a set of security and privacy functions for Ericsson products. The product organization responsible for each Ericsson product will analyze, decide and document the applicability and compliance to the GPR security and privacy requirements. Not all functions listed in the GPR are compulsory, nor applicable, for a specific product. In addition, products may be designed to support privacy and security requirements that are not in the GPR.

One key deliverable of a Risk Assessment process (see 6.6.2 below) is to identify a list of security and privacy functions which are required to minimize known risks to an acceptable level.

#### 6.6.2 Assurance

Assurance activities are divided to three levels; basic, advanced and tailored level. All basic level assurance activities shall be performed by the product development, given that the activities are applicable. Advanced level activities can be performed for parts of products with need of high security assurance. Tailored level activities are used for products, or parts thereof, where product specific assurance requirements exist.

The most prominent assurance activities leveraged by Ericsson are Risk Assessments, Secure Coding practices, Vulnerability Analyses and Hardening. These are defined as such:

- A Risk Assessment will identify risks related to the product when used in the customer’s network, after which it will either create controls to reduce the risks or suggest alternative means to reduce the risk exposure of the customer. Unacceptable risks will be mitigated with risk treatment actions.
- By following secure coding practices, Ericsson reduces the possibility of design flaws and implementation bugs during the software development. Secure coding activities aim to reduce flaws and weaknesses in the software code through code reviews and various static and dynamic scanners and tools.
- The Ericsson way of performing Vulnerability Analysis (often referred to as Vulnerability Assessment within the industry) comprises the testing and verification (including penetration testing) activities which are designed to identify weaknesses and vulnerabilities present in the product or solution. The vulnerability analysis verifies security characteristics and security configuration of the product/solution and identifies new vulnerabilities through both black box and white box testing. Remaining vulnerabilities shall be documented with mitigation proposals. A Vulnerability Analysis shows that Risks discovered in the Risk Assessment activity are sufficiently controlled (or mitigations documented) in the final product.
- Hardening means increasing product security by reducing its attack surface. Hardening is a design and a configuration issue as well as a deployment issue. Hardening ensures that the product is configured in a manner that minimizes the risk of unauthorized access, including system compromise. Hardening includes, for example, removal of unnecessary software, installation of the

latest patches, disablement of insecure services and replacement of default passwords.

#### 6.6.3 Documentation

The documentation aspect in SRM defines security and privacy specific customer documents. The documents defined in SRM are the Hardening Guidelines, Security and Privacy User Guide, and the Security Test Results report.

#### 6.6.4 Enabling Product Near Security Services

Ericsson’s product-near security services are currently handled separately by the service organizations and are independently defined by the products. Currently, SRM does not define specific mandatory deliverables in this area. Typical deliverables are security and privacy training recommendations, solution level integration guidance and potential deployment-time hardening activities that need to be included in customer delivery projects.

#### 6.3 Avoiding vulnerabilities

The work to avoid vulnerabilities includes product and feature risk assessments and secure design, secure coding principles and use of analysis tools, and supply chain security considerations.



The Ericsson process emphasizes the importance of risk assessments to identify needs for extra controls and to avoid functionality that could be abused by a malicious actor. Risk assessments serve to identify exposed parts of a product which require extra attention in coding and testing.

The use of secure coding principles contributes to overall code quality and robustness. Ericsson is committed to the idea that secure code is good code and that good code is secure code. Apart from mandating allocating time for programmers to learn about secure coding practices, Ericsson also provides the design teams with a wide selection of code analysis tools as part of the development environment and infrastructure.

Supply chain security considerations is prime concern for all industries and perhaps especially for telecom. For Ericsson, we believe it is business critical to address these concerns to the satisfaction of the customer. To this end, an internal program continuously works, with the support of senior management, to apply the standard risk management cycle of assessing risk, planning mitigations, deploying controls, and evaluating the results.

#### 6.4 Detecting flaws

Nobody expects software to be free from flaws and much of the total design effort goes into testing. However, testing for security vulnerabilities very much is about crafting input that lies outside what is expected and tested for normal operations, and that cause the system to misbehave in a way that can be exploited by an attacker.

To design such testing, special competence is a prerequisite. Ericsson maintains Vulnerability Assessment teams that, with their knowledge, experience, and tools regularly prevent such flaws from graduating to the release phase. Fuzzing is one technique that is used extensively to randomly introduce unexpected variations into protocol messages that are processed by a product. Where available, state-of-the-art commercial tools are used, but for more specialized interfaces, Ericsson works to develop inhouse support for fuzzing and other tests methods.

#### 6.5 Vulnerability watch

One enabler for building very complex systems is the abundant availability of well performing third party components and libraries. The reuse of proven code, both open source and commercially licensed, enables most software companies to concentrate on creating added value, rather than reinventing the wheel. Unfortunately, however, including third party functionality comes at the price of third party vulnerabilities.

To address this challenge, Ericsson has



established a central database service that catalogues all third part components used in Ericsson products. The Ericsson Product Security Incident Response Team (PSIRT) continuously monitors both public and subscription-based sources for alerts on discovered vulnerabilities in third party software. The Ericsson database allows external notification to be instantly mapped to Ericsson products. Where there is a match, an alert is sent internally to the affected product development organization that must provide an analysis of how the reported fault impacts the Ericsson product in question. The answer must be provided within strict time frames, depending on the severity of the vulnerability.

#### 6.6 Vulnerability remediation

If a product is affected by a vulnerability, a trouble ticket will be issued, and a remediation will be implemented and provided through standard support channels. Ericsson applies a one-track approach for new developments, but for each released software version a maintenance track is opened that allow faults (of all kinds) to be corrected without requiring an upgrade to a later version of the product. Normally, maintenance releases are pre-scheduled, but if urgently needed, unplanned emergency corrections can also be made.

#### 6.7 Ericsson's Product Security Incident Response Team

At Ericsson, PSIRT (Product Security Incident Response Team) is responsible for actively and continuously monitoring new vulnerabilities early on and making sure they are fixed timely throughout Ericsson's portfolio.

As PSIRT experiences in security incident response regularly testify, the most common way to fail in security is to have shortcomings in the configurations of the network, elements of a network or poor network operational procedures. In such

situations, breaches often go unnoticed due to lack of monitoring of log files and data flows. When an incident is noticed, the investigation becomes very difficult, if not impossible, due to lack of traceability. If many internal users have administrator permissions to the network or subsystems accountability maybe lost. Often also the log files are not protected and stored long enough, or backup restoration is not tested.

All these deficiencies in basic operational procedures contribute greatly to increased risk of network security breach and exaggerate the damage in the event of a security breach. The same flaws may allow the attackers to hide their tracks effectively, resulting in increased difficulty addressing detection, attribution and complete remediation.

Good network design in deployment is needed to limit options to laterally extend the attack. Breach in security of one network component should not expose the rest of the network to the attacker. The principle of defense in depth explains how security controls must exist on every layer and every stage, necessary as no layer can be trusted fully i.e. there is no such thing as a 'secure internal network'. Solid operational procedures will include segregation of duties of network administrators and provide traceability back to every change and action done in the system. No one individual should have unaccountability in making significant changes to the system alone.

It is widely understood that prevention alone is not enough. Resources need to be assigned to active detection of attacks, and respond in a time sensitive manner during and after an attack e.g. eviction of the successful threat actor. Exercised activities with the goal of returning to normal operation after incident are vital. Immediately after response, removing exploited vulnerabilities and weaknesses are essential to avoid known vulnerabilities being exploited again.



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# Glossary

## 1G

First generation wireless. Analog technology supporting voice.

## 2G

Second generation wireless. Introduced SMS, MMS and data transmission.

## 3G

Third generation wireless. High data speeds, always on data access and increased voice capacity.

## 4G

Fourth generation wireless. An all IP based network system with increased data speeds over.

## 5G

Fifth generation wireless. Targets high data rate, reduced latency, energy saving and massive device connectivity.

## 3GPP

The 3rd Generation Partnership Project, a collaboration between groups of telecommunications standards associations.

## Artificial Intelligence (AI)

The ability of a digital system to perform tasks commonly associated with intelligent beings.

## Authenticate

The process of determining whether someone or something is, who or what it declares itself to be.

## Active detection

The process of proactively identifying the occurrence of a breach.

## Baseband unit

A subsystem in a telecommunications device that processes baseband radio signals.

## Botnets

A network of computing devices infected with malicious software and controlled as a group without the owners' knowledge.

## Breach

A security incident where the confidentiality, integrity or availability of a system has occurred.

## Continuous integration (CI)

The practice of merging all developer working copies to a shared repository several times a day.

## Compartmentalization

Functions that aim to isolate possible security breaches from escalating from one part of the network to another.

## Core

The "backbone" network which provides the interconnect between other networks and systems to exchange information such as calls and data, including the special purposes servers and databases.

## Distributed Denial of Service Attack (DDoS)

A denial of service (DoS) attack is a malicious attempt to make a server or a network resource unavailable.

## Distributed Cloud

Interconnecting data and applications served from different locations.

## Edge computing

Computation and processing of data is performed on distributed device nodes as opposed to primarily taking place in a centralized cloud environment.

## Encryption

The process of converting information or data (plaintext) into encoded format (ciphertext) to prevent unauthorized access.

## European Telecommunications Standards Institute (ETSI)

A non-profit organization that establishes telecommunications standards for Europe.

## Evolved Universal Mobile Telecommunications System Terrestrial Radio Access Network (EUTRAN)

The air interface in an LTE cellular network.

## Functional element

A manageable logical entity uniting one or more physical device.

## Hardening

Increasing product security by reducing its attack surface. Hardening ensures that the product is configured in a manner that minimizes the risk of unauthorized access and system compromise.

## Hypervisor or container environment

The separation a computer's operating system and applications from the underlying physical hardware.

## Internet Engineering Task Force (IETF)

The body that defines standard Internet operating protocols.

## IMS

IP Multimedia Subsystem or IP Multimedia Core Network Subsystem enables the convergence of data, speech, and mobile network technology over an IP-based infrastructure.

## Incident

An event that results in unauthorized access, loss, disclosure, modification, disruption, or destruction of data.

## Interface

A shared boundary across which two or more separate components of a computer system exchange information.

## Interoperability

A characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems.

## Internet of Things (IoT)

The interconnection via the Internet of computing devices embedded in everyday objects to enable them to send and receive data.

## IP connectivity

A network or interface that supports Internet Protocol (IP) communications.

## Internet Protocol security (IPsec)

A framework of open security standards for helping to ensure private, secure communications over Internet Protocol (IP) networks using cryptographic security services

## MACsec

A security standard which defines connectionless data confidentiality and integrity on ethernet links.

## Integrity protection algorithm

A software algorithm that is designed to maintain and assure the accuracy and completeness of data.

## Latency

Delays in transmitting or processing data.

## Layer

Level of abstraction in a network protocol stack.

## Long Term Evolution (LTE)

A standard for 4G wireless broadband technology that offers increased network capacity and speed to mobile device users.

## Lawful intercept

Facilities in telecommunications networks that allow law enforcement agencies with legal authorization to wiretap individual subscribers.

## Logical network

A way of representing networks that have the same connectivity properties.

## Massive machine type communication

Automatic data generation, exchange, processing and actuation among intelligent

machines on a large scale with the quality of transmitting low volume of non-delay sensitive information.

#### **Mean time between failures**

Predicted elapsed time between inherent failures of a system.

#### **Metadata**

Summarization information of data, for example the duration of a call or who was called.

#### **Mobile Broadband**

Wireless internet, often through a mobile telecommunications network.

#### **Network slicing**

Virtualization capability that allows multiple logical networks to run on top of a shared physical network infrastructure.

#### **Domain Name System (DNS)**

A method and infrastructure for converting alphabetic names into numeric IP addresses.

#### **Dynamic Host Configuration Protocol (DHCP)**

A protocol for assigning dynamic IP addresses to devices on a network.

#### **Network Function Virtualization (NFV)**

The visualization of network services that traditionally run on proprietary, dedicated hardware

#### **Next Generation Radio Access Network (NG-RAN)**

Infrastructure for 5G.

#### **Port-based authentication**

A mechanism to authenticate devices wishing to attach to local access network.

#### **Radio Access Network (RAN)**

Technology that connects individual devices to other parts of a network through radio connections.

#### **Geographical redundancy**

Replicates data between two geographically distant sites so that applications can switch from one site to another in the case of failure.

#### **Path and link redundancy**

An alternative channel of communication in the event of a failure.

#### **Global System for Mobile communication (GSM)**

Also known as 2G technology employed in second generation telecommunication networks.

#### **Generic Product Requirements (GPR)**

Ericsson's set of requirements that define the needed product functionalities, security and

privacy related product documentation, and the needed evidence about security assurance activities.

#### **Radio jamming**

The deliberate jamming, blocking or interference with authorized wireless communications.

#### **Radio unit**

A remote radio transceiver that connects to an operator radio control panel via electrical or wireless interface.

#### **Roaming**

When a cellular customer makes and receive voice calls, send and receive data when travelling outside the geographical coverage area of the home network.

#### **Payload**

The part of transmitted data that is the actual intended message.

#### **Penetration testing**

An authorized simulated attack on a computer system, performed to evaluate the security of the system.

#### **Product Security Incident Response Team (PSIRT)**

Ericsson unit that is responsible for actively and continuously monitoring new vulnerabilities and making sure they are fixed timely throughout Ericsson's portfolio.

#### **Scaling mechanisms**

Mechanism to increase or decrease capacity to meet the required demand at a given moment.

#### **Secure coding**

The practice of developing computer software in a way that guards against the accidental introduction of security vulnerabilities.

#### **Selective dropping/throttling**

A technique to discard or queue incoming traffic, often in response to network congestion.

#### **Service Based Architecture**

System architecture centered around services that can register themselves and subscribe to other services. Employed in 5G core networks.

#### **Software-Defined Networking (SDN)**

An architecture that aims to make networks agile and flexible that enables providers to respond quickly to changing business requirements.

#### **Signaling (traffic)**

The exchange of information between involved points in the network that sets up, controls, and terminates a call or data session.

#### **Security Reliability Model (SRM)**

Ericsson's methodology to achieve security and privacy ambition in products.

#### **Quality of Service (QoS)**

Technology that manages data traffic to reduce packet loss, latency and jitter the network.

#### **Transport network**

Connects the access network with the core or base stations with each other within the radio access network

#### **Trusted Execution Environment**

A secure area of a processor used to guarantee code and data loaded inside is protected with respect to confidentiality and integrity.

#### **Topology**

The arrangement of a network, including its nodes and connecting lines.

#### **Trusted Platform Module (TPM)**

A specialized chip used to carry out cryptographic operations like the storing of encryption keys to secure information which is usually used by the host system to authenticate hardware.

#### **User plane data**

The part of transmitted data that is the actual intended message.

#### **Universal Mobile Telecommunication System (UTMS)**

Also known as 3G.

#### **Voice over LTE (VoLTE)**

A technology that supports voice calls over a 4G telecommunications network.

#### **Vendor credentials**

Vendor unique information used to identify hardware such as radio base station so that it can be identified and trusted in a specific operator network and used for bootstrapping operator keys.

#### **Virtualization**

To create a virtual version of a device or resource, such as a server, storage device, network or operating system.

#### **Vulnerability**

A weaknesses or gap in a system that can be exploited by threats to gain unauthorized access to an asset.

