Service Level Agreements for 5G and Beyond: Overview, Challenges and Enablers of 5G-Healthcare Systems

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Abstract

Service level agreements (SLAs) can enable 5G-enabled medical device use cases by documenting how a medical device communication requirement is met by the unique characteristics of 5G networks and the roles and responsibilities of the stakeholders involved in offering safe and effective 5G-enabled healthcare to patients. However, there are gaps in this space that should be addressed to facilitate the efficient implementation of 5G in healthcare. Current literature regarding SLAs for 5G-healthcare is absent. This work aims to bridge these gaps by identifying key challenges, providing insight, and describing open research questions related to 5G-healthcare systems. After presenting an overview of SLAs, reasons for insufficiency of traditional SLA approaches for 5G networks are identified. Then, 5G SLA challenges during various stages of the SLA lifecycle are identified. Practical aspects for 5G-healthcare SLA development and implementation are highlighted and considerations are recommended to help enable 5G-healthcare systems. Open questions that the research community can help answer to promote the safe use of 5G and beyond communication technology in healthcare are also identified. These include aspects from both the physical layer and the core side of 5G.

Introduction

The key features of 5G and beyond networks, such as high multi-Gbps peak data speeds, ultra-low latency, massive device connectivity, reliability, increased network capacity, increased availability, and data-driven insights are set to create a significant impact in healthcare. Several healthcare use cases, such as telesurgery, connected ambulance, remote diagnosis, IoT where a plethora of medical devices including vital sign monitors, devices using augmented and virtual reality, implantable devices, and other types can benefit from augmented 5G-based connectivity

However, ensuring that various 5G-enabled medical devices receive the communication services needed per their unique requirements is important. Documenting assurances of 5G network performance can be in the form of a service level agreement (SLA), which is a commitment between two or more parties that documents the details of various aspects of services that one party will provide to the other.

There are gaps in literature regarding 5G-healthcare SLAs that should be addressed to facilitate the implementation of 5G-enabled medical devices. SLAs for 5G and beyond networks are addressed in a limited number of articles that primarily aim to propose specific technical solutions and the evaluation of those solutions. No previous work has comprehensively investigated whether traditional SLAs are adequate for 5G and beyond networks or detailed the challenges and limitations that can render them insufficient, which are gaps that we fill in this work. Moreover, to the best of our knowledge, there is no existing work that addresses any aspect of SLAs in 5G-healthcare systems.

Materials and Methods

First, an overview of SLAs is conducted using literature reports from both academia and industry, including SLA types, building blocks, metrics, management and definitions as shown in Fig. 1. These traditional SLA approaches are then analyzed in the context of 5G networks. By doing so, reasons for insufficiency of traditional SLA approaches for 5G networks are identified. Following that, the scope is further narrowed down to various stages of SLAs, including SLA development, fulfilment, management and assurance and 5G SLA challenges during these stages of the SLA lifecycle are identified. Based on that, practical aspects and considerations for 5G-healthcare SLAs are highlighted to help enable 5G-healthcare systems, including risk management and cybersecurity aspects of 5G-enabled medical devices. Open questions and future research directions related to 5G-healthcare are also identified.

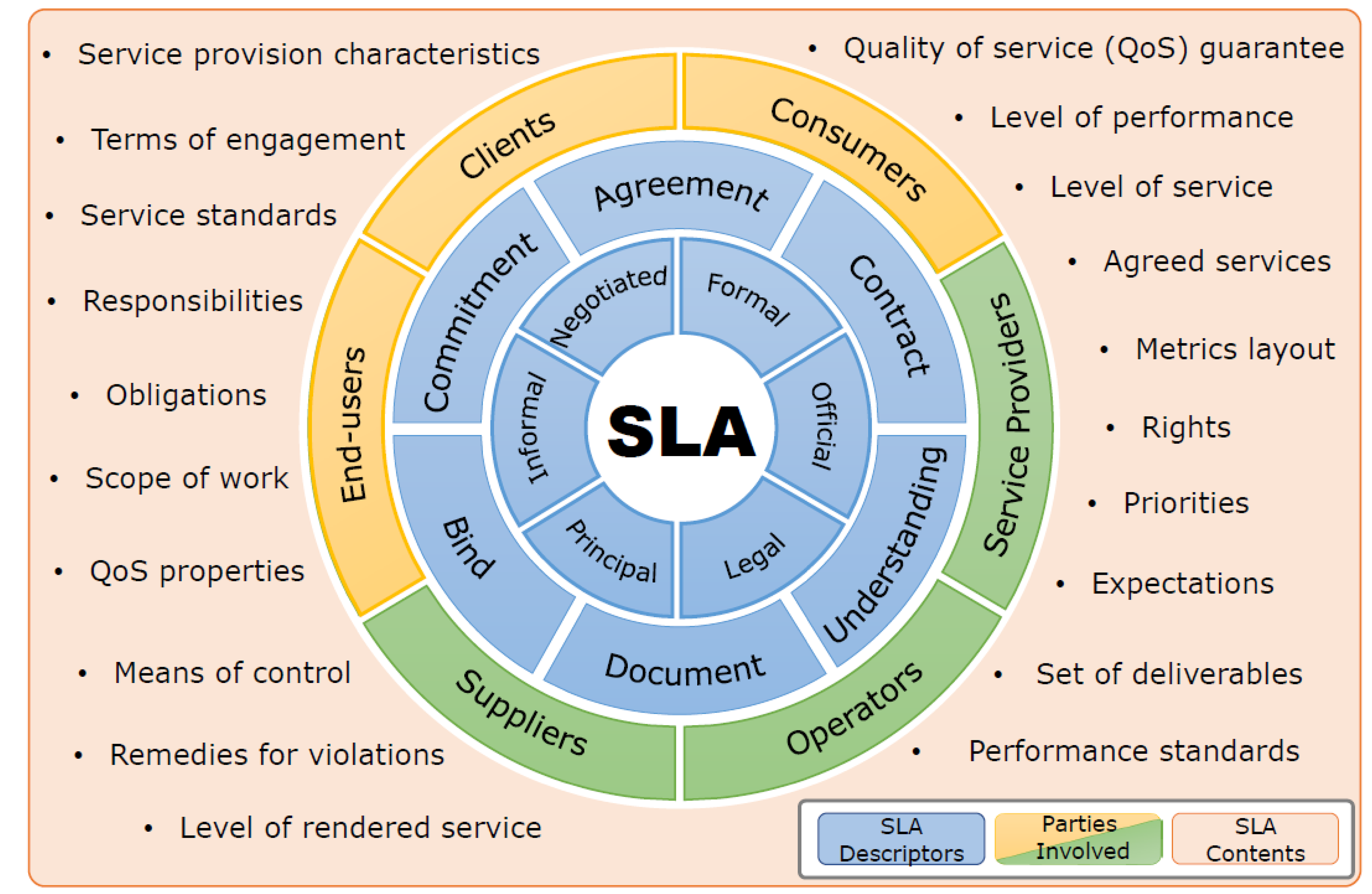

Figure 1. SLA definitions. This figure should be read as follows: an SLA is [SLA descriptors (blue)] between [parties providing (green)] and [parties receiving services (yellow)] that consists of [SLA contents (orange)].

Results and Discussion

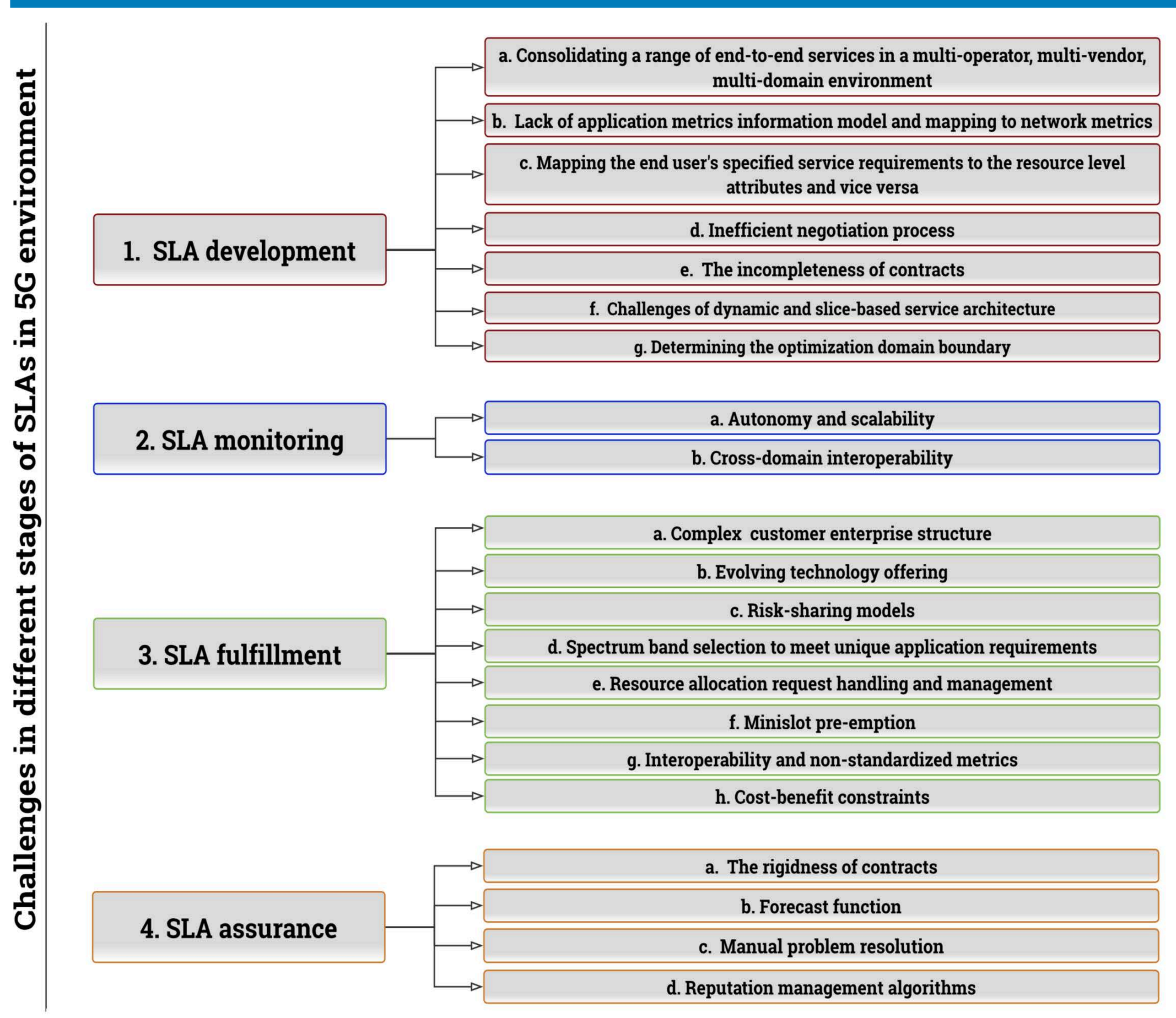

Figure 2. Challenges of 5G SLAs categorized according to the development, monitoring, fulfillment and assurance SLA parts.

Traditional SLA approaches are insufficient for 5G-healthcare systems because new and evolved 5G technical characteristics are not considered in existing practices of SLA generation and management, such as 5G heterogeneous environment including mm-wave band bringing in challenges of cell discovery, cell association, beam alignment and frequent handovers; the adaptive numerology, mini-slots and bandwidth adaptation in 5G require new mechanisms for resource allocation on symbol level, slot aggregation and priority based pre-emption of normal transmission.

5G network slicing requires the development of new scheduling, dynamic resource allocation and admission control policies in per-slice SLAs.

5G SLA challenges are identified and described during the various stages of the SLA lifecycle as summarized in Fig. 2.
Cybersecurity is particularly important for medical devices and addressing it in SLA promotes transparency. A list of potential cybersecurity threats in 5G are categorized based on the susceptible 5G system component and the affected healthcare application as shown in Table 1.

Table 1. Cybersecurity threats to the 5G ecosystem (an important consideration in 5G-Healthcare SLAs) with corresponding affected healthcare applications.

Point of attack	5G security threats and attacks type	Affected Healthcare Application: Medical IoT (e.g., wearables, implantable devices, on-site equipment, home-based medical devices)	Affected Healthcare Application: Remote Medical Procedures (e.g., telesurgery, teleconsultation, ambulance drone, telemedicine, in-ambulance treatment)	Affected Healthcare Application: Medical Data Management (e.g., confidential health records, personally identifiable information)
Internet/Other Operator	Security Policy Conflicts		x	x
Internet	Pharming		x	x
	Trojan		x	x
	Virus		x	x
5G Central Cloud	Hijacking Attack		x	x
	Man-in-the-middle Attack		x	x
	Configuration Attack		x	x
	Saturation Attack		x	x
	Signaling Attack		x	x
5G Central Cloud/ 5G Edge Cloud	Slice/Resource Theft		x	x
5G Central Cloud/ 5G Edge Cloud/5G RAN	Distributed Denial of Service (DDoS) Attack	x	x	x
	Denial of Service (DoS) Attack	x	x	x
	Penetration Attack	x	x	x
5G RAN	Reset and IP Spoofing	x	x	
	Scanning Attack	x	x	
	Semantic Information Attack	x	x	
	Signaling Storms/Signal Jamming	x	x	
	International Mobile Subscriber Identity (IMSI) Catching Attack	x	x	
	Illegal Intercept	x	x	
	Flash Traffic	x	x	
	Fake Base Station Attack	x	x	
End user	User Identity Theft	x		
	Security Key Theft	x		
	Advanced Malware	x		
	Firmware Hacks	x		
	Device Tampering	x		
	Spyware	x		
	IoT Botnets	x		
	Ransomware	x		
	Battery Draining Attack	x		
	Identification Attack	x		
	Privacy Breach	x		

Conclusion

In this work, we present an overview of SLAs, identify the challenges for SLAs in 5G and beyond networks, highlight practical aspects for SLA development and implementation, and recommend considerations to help enable 5G-healthcare systems. These include topics, tradeoffs, and practical implementation considerations in 5G network resource allocation like provisioning mini-slots for a specific service, optimal triggering of mini-slots pre-emption, optimizing device performance when using bandwidth adaptation, network slice sharing modes, and dynamic network resource optimization. Research is also needed to understand the integration of user equipment (UE) miss-association probability to millimeter wave (mmWave) cells in the medical device risk evaluation and strategies to address it in the SLA. With increasing network complexity, the need arises for adaptive algorithms to reduce the large set of observable network counters and metrics and facilitate efficient network monitoring for service assurance. Additionally, algorithms are also needed to flexibly map and optimize network configuration parameters to meet desired healthcare application while maintaining business objectives for all stakeholders. Addressing these research challenges promotes the development of robust SLAs to ensure that device manufacturers, network service providers, and regulators share a common framework for safe healthcare service delivery.