Reliability In Telecommunication Systems

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Abstract: **Telecommunication systems reliability is crucial as many day-to-day activities would be almost impossible for the end-users if something goes wrong unannounced. Reliability is the word used in the design of telecommunication systems to ensure that the system performs as expected in a given period of time. There are several telecommunication systems, but the paper will focus mainly on mobile wireless networks which discussed mobile wireless systems, architecture and reliability and survivability techniques.**

Keywords- Reliability, availability, survivability, telecommunication, mobile wireless networks, fault tolerance, redundancy.

I. INTRODUCTION

There has never been a system designed or created that is immune to faults, errors, or failure. These elements are inevitable in any system but reducing or masking them to the lowest bare minimum provides trustworthiness or dependability of the system. So, when can we say a system is dependable? Well, there is no one single word, value, or description to define the dependability of any system; however, there are established and recognized attributes in the field of fault tolerance and dependability that can be used to understand, measure, and explain dependability—Reliability, Availability, Maintainability, Safety, and Security are examples of these attributes. These attributes and a means of achieving them in a system are always at the forefront of system designers. When it comes to telecommunication computer system design, achieving reliability becomes a crucial challenge since the system must be operational over a longer time period, and the rate of failure becomes crucial as the system is near the end of its life cycle. We can consider a system reliable or trustworthy if we have assurance in its correctness and/or usefulness; however, how can we know or say a system is reliable? The most helpful approach to thinking of reliability is in terms of consistency; that is, the more we subject a system to testing over and over again and get the same answer, the more we can trust that system. This paper will cover reliability in a telecommunication system with a focus on 5G mobile wireless networks.

II. BACKGROUND

Telecommunication systems allow for communication over great distances using electromagnetic waves, and they rely on certain software and hardware components to work. There are nodes and links in the telecommunications network that allow people to interact with one another. This includes the internet, the phone network, computer networks, and radio broadcasting systems. System nodes are the communication equipment we utilize, such as our cell phones or computers [1].

First Generation (1G): Mobile cellular 1G standards, such as Nordic Mobile Telephone (NMT) in Nordic nations, were first implemented in 1981, decades after the first commercial analogue mobile communication systems were introduced in the 1950s and 1960s around the globe.

Second Generation (2G): To build a pan-European 2G mobile communication system, the European Conference of Postal and Telecommunications Administrations (CEPT) made the decision in 1982. Beginning in 1991, the leading 2G standard, the Global System for Mobile Communications (GSM), was put into place. The adoption of digital transmission and switching technology marked the introduction of 2G. High-capacity phones and minimal data services have been the primary functions of 2.5G since its introduction in 1995. The CDMA (code division multiple access) technologies with a 1.25 MHz bandwidth were implemented in the United States. Europe, on the other hand, transitioned from GSM to EDGE and GPRS.

Third Generation (3G): The third-generation (3G) wireless communications technology was introduced in 1999 and handled both voice and data. The Worldwide Telecommunication Union (ITU) has produced its first international standard system, 3G. At 5MHz, the bandwidth of WCDMA (Wideband Code Division Multiple Access), 3G utilizes.

Fourth Generation (4G): 4G, high-speed data transmission and voice technology were already in use by 2013. Two kinds of 4G networks exist. The WiMAX (Worldwide Interoperability for Microwave Access) technology was developed by the United States and is based on orthogonal frequency division multiplexing, which was first developed for use with WLAN (OFDM). WiMAX was followed by the

LTE system, which was introduced in 2012. Both LTE and WiMAX have several characteristics. The combined bandwidth of the two systems is 20 MHz. LTE is supported by the main cellular carriers, and most countries have already issued licenses for 4G utilizing LTE systems now under development. Licensing is too expensive when done via an auction.

Fifth Generation (5G): We are in the fifth-generation system, and 5G has been making its way into network systems since the beginning of 2020; 5 G has yet to be officially defined by standardization bodies. An ultrahigh-capacity, ultrafast data system with new design specifications targeted toward energy-elicited devices and reduced operating costs for operators will be implemented. End-users may expect a seamless communication experience, not just a single new technology, with the 5G network ecosystem. A paradigm shift in design is required to go from a single-discipline to a multi-discipline system [9], [10].

Telecommunications systems have a long history of being designed with reliability in mind, and this design criterion is typically specified in terms of availability and reliability, so a contract called service level agreements (SLAs) is commonly used to specify a performance target Figure 1. Customers must have reasonable expectations of the service they seek, and

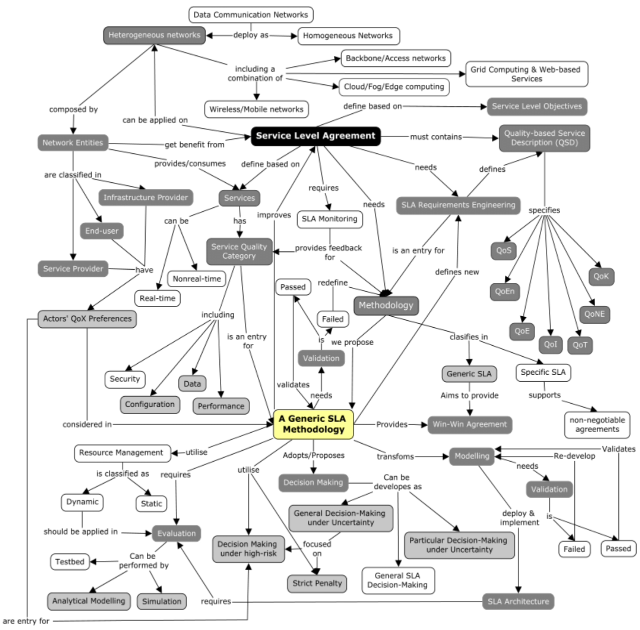

FIGURE 1. SLA CONCEPTUAL MAP [3]

Service providers (SPs) must ensure that their service can achieve the desired outcomes [2],[5]. Telecommunications is a vast field that includes satellite, fibre-optics, microwave, mobile, and wireless networks, among others, and this paper will focus on mobile wireless networks. Companies that provide clients with communication and data services are known as SPs. When it comes to network management, service providers (SPs) have the option of managing their own networks or integrating the services of other service providers (SPs) [3]. As shown in Figure 1, the suggested conceptual map for establishing a comprehensive and general SLA methodology for communication and computer networks incorporates every criterion for high quality into the implementation of SLAs. SLAs may be used to provide end EU and/or SP with a guaranteed level of service quality by starting in the top-center box labeled Data Communication Networks. To get an adequate SLA, the model should be constructed using service level objectives SLOs) and include quality-based service descriptions (QSDs). All-important ideas, such as requirements engineering and SLA monitoring, are considered in this proposed conceptual map to give appropriate feedback and supply [3].

III. MOBILE WIRELESS NETWORK SYSTEMS

Mobile wireless networks account for a significant amount of contemporary communications system investment, infrastructure, and research. Manufacturers, operators, and consumers all make investments to keep up with consumer demand for ever-increasing performance from their systems. The performance of a system is directly related to the architecture of mobile wireless networks with set availability objectives. The need for uninterrupted wireless service develops as more people give up their landline phone connections [2]. The world's reliance on wireless and mobile services is increasing, yet wireless network infrastructures may not be able to meet the rising demand. Evolving wireless applications, such as e-commerce and high-bandwidth internet, might be hampered by failures in addition to present voice and data consumption. The ability of wireless (and wireline) networks to prevent or recover from failure is assessed in 3 ways:

- *Reliability* is the capacity of a system to carry out a certain set of operations under specific circumstances and during specific operating periods that have been predetermined.
- *Availability* is the system's capacity to fulfil its duties at any given time under particular circumstances. The amount of time it takes for a system to recover from a failure is a measure of its overall availability.
- *The number of subscribers* impacted and the number of services affected may all be used to gauge a network's survivability in the event of a service outage caused by a breakdown of a network infrastructure component [2].

In order to support a huge installed base of equipment and millions of users, network engineers must be familiar with issues like trade-offs, network sparing, and system availability, while designing networks. In order for a mobile wireless network to function, various core network components must be present. This chapter's methods for assessing the mobile wireless network's availability and dependability are familiar with the previous ones. Multiple base stations serve a large number of customers geographically dispersed (BS). Network core and base transceiver station (BTS) parts must be given particular care when it comes to backhaul. Contractual SLA availability and performance parameters must be established by a third-party network operator supplying backhaul. Managing wireless backhaul network designs requires the same level of attention as managing other mobile wireless components or subsystems in a network [2]. Many different mobile wireless network standards and technologies are in use across the globe, and their network topologies are relatively similar in most cases. The air interface is the most notable distinction between the two systems. All mobile wireless networks have the same reliability and availability concerns [2].

IV. MOBILE WIRELESS NETWORK ARCHITECTURE

Mobile wireless networks make use of a complex interconnected network of systems to provide data services and wireless voice to subscribers. Network management, end-to-end call setup, data traffic flow, and call switching are all controlled by network elements. Design philosophies and fundamental building blocks of various mobile wireless technologies (i.e., LTE, UMTS, CDMA, and GSM) may differ, but they remain consistent across all of them [2]. As seen in Figure 2, the architecture of a typical cellular communications services system includes several components, any of which might fail and affect varying amounts of users. There is a wide range of mobile wireless network standards and technologies in use across the globe today. Technology deployment networks tend to have a similar structure. The air interface is the most important distinction between the technologies.

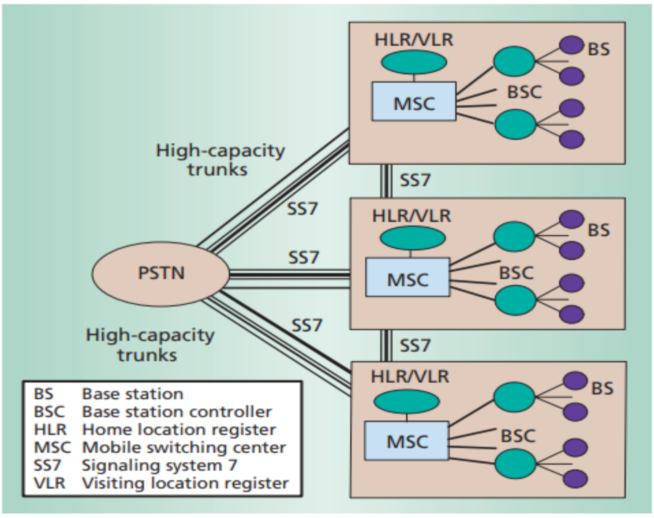

FIGURE 2. CELLULAR COMMUNICATION ARCHITECTURE [4]

The base station (BS): Cellular phones are supported by a base station (BS), which allocates resources that allow customers to continue ongoing calls or start new ones if they relocate.
Base station controller (BSC): Switching assistance is provided by the base station controller (BSC) for a number of nearby base stations, which serve thousands of customers. Wireless microwave connections may be used to connect base station controllers to base stations, although they've traditionally been wired or fiber-optic.
Mobile switching center (MSC): More than 100,000 people may be served by an MSC, which is a big switch. Wireless connections between base station controllers and mobile switching centers are also becoming more prevalent.
Home location registers (HLR): If you're a permanent resident of the region, you'll be tracked by VLR or HLR.
Signalling system 7 (SS7): Call setup between mobile PSTN and switching centers is handled by this service.
*High-capacity trunks (T1 or T3)***:** This support calls between PSTN and mobile switching centers. Nearly the whole mobile switching center's customers—possibly hundreds of thousands of people—could be affected if a PSTN trunk, SS7, mobile switching center, PSTN connection, VLR or HLR went down in this scenario [4].

V. MOBILE WIRELESS NETWORK RELIABILITY AND REDUNDANCY

Mobile wireless networks should be designed with set reliability and availability objectives in mind if they are to achieve central-to-system performance. The need for uninterruptible wireless service is growing as more and more people are connected. Network engineers must have a deep grasp of design trade-offs, network sparing, and system availability when dealing with millions of customers and a big installed base of equipment. Generally, redundancy, in which systems, especially critical modules, are replicated by ***n-versions*** of the same module, is a common solution. Hardware is the most established area in the overall field of fault-tolerant computing. From switchboards to space flights, several hardware fault-tolerance approaches have been devised and used. The expense of the additional hardware required has been the main impediment to the widespread adoption of hardware fault tolerance in the past. It's becoming less of a drawback as hardware prices continue to decline, and the usage of hardware fault-tolerance technologies is likely to rise. Massive redundancy may still be limited in many applications by other restrictions, like power consumption [9],[10]. However, wireless carriers should also concentrate on components that have the least effect on consumers, such as those that have a shorter mean-time-between-failures (MTBF) and higher mean-time-between-recoveries, to decrease the frequency of outages and speed up the recovery process after an outage. The MSC is a critical component of the network subsystem and is required for the mobile wireless network to function; it is in charge of routing voice and SMS traffic, as well as end-to-end mobility management and call management. Most generally, it is a redundant network piece that services a whole area. Several geographically dispersed MSCs are routinely deployed by big carriers in order to spread the network's load.

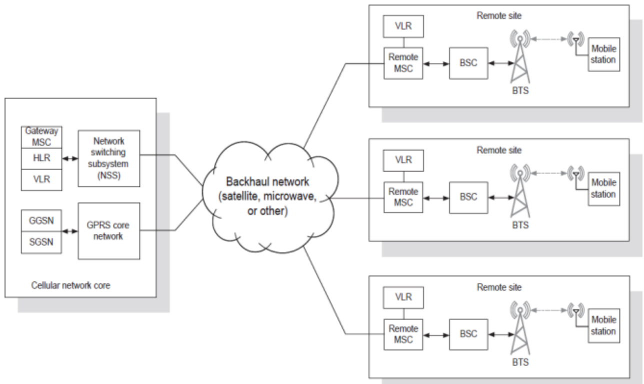

FIGURE 3. BLOCK DIAGRAM FOR DISTRIBUTED MSC [2]

Calculating wireless-to-wireless service availability in a satellite-served community and comparing this availability to that of a central MSC topology is achievable. It is possible to estimate the wireless service availability in the centralized MSC topology by (1).

$$A_{service} = A_{core} \times A_{backhaul} \times A_{BSC/BTS} \quad (1)$$

Where $A_{service}$ is the availability of the wireless service. As long as a subscriber can successfully connect to another subscriber through wireless in the local, satellite-served area, service is deemed to be operational. A_{core} refers to the availability of the system's essential components. A 99.995% level of availability is assumed for all network subsystem services necessary for call completion. There is 99.8% uptime on the backhaul communications link, which is represented as $A_{backhaul.}$ In the context of wireless networks, $A_{BSC/BTS}$ refers to the network's BTS and its traffic processing functions BSC (the radio access network or RAN). Backhaul outages in locations where local calls must be maintained may benefit from a distributed MSC network. Distributed MSCs deployment may help networks that rely on satellite backhaul. As shown in Figure 4, even if the backhaul fails, wireless-to-wireless calls may still be made between phones serviced by the isolated MSC and those in a satellite-served community, and this can be contrasted with the availability of wireless-to-wireless calls in that community [2], [7].

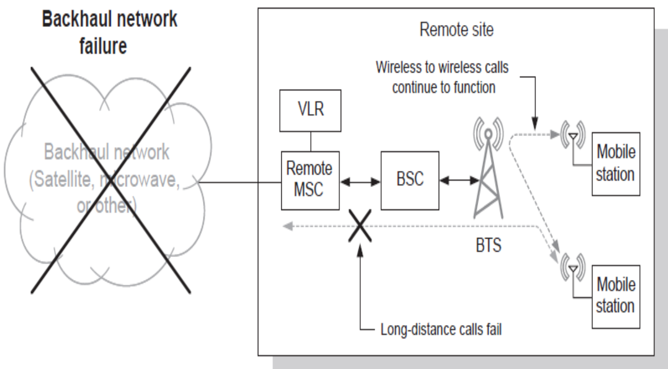

FIGURE 4. BACKHAUL NETWORK FAILURE SCENARIO [2]

Figure 5 shows an essential network infrastructure with separate network switching subsystem (NSS) components linked to two high availability packet switching elements. MSC and its accompanying voice and data switching components are clearly of equal importance to network availability. When packet switching and routing parts are built with different performance aims than mobile wireless network elements, a system will not be able to meet its performance goals. The study of systems that utilize third-party backhaul lines is of special interest. To guarantee that contractual SLAs are satisfied, the network operator must use prudence.

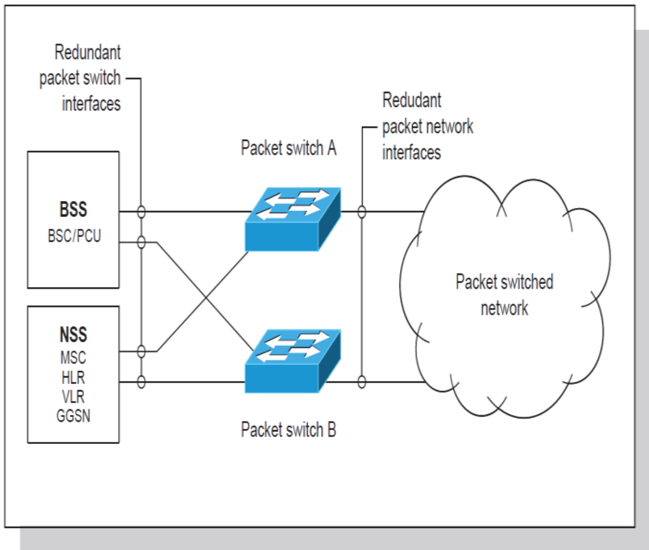

FIGURE 5. BACKHAUL NETWORK FAILURE SCENARIO [2]

VI. IMPACT AND MITIGATION OF MOBILE WIRELESS COMPONENTS FAILURES

When minor components fail, their impact may be insignificant on the users as the damage would be minimal. Most customers would be unable to utilize the service, and many user connections will be disconnected in the event of a serious breakdown. Initial registration and call delivery will be lost for cellular and PCS users. Because many central office switches may be used as mobile switching centers if properly placed and controlled, they provide a high level of reliability. A wide range of wireless and mobile network components are vulnerable to failure. Location data for mobile users is stored in a database by every network. Data may be stored over various networks in order to prevent data loss. To decrease base station failures, several configurations and architectural designs may be used, such as linkages between BSs and MSCs, multifunction/multi-mode devices, and overlay networks. In addition, base station topologies improve survivability by reducing radio connection failures by enhancing the signal-to-noise ratio. The twelfth digit Based on protocol and frequency translations and content adaptation, a user may access one of several accessible wireless networks on an overlay network that has multiple universal access points (UAPs). In big networks with thousands of components, failures are more probable even if components don't break for months or years. Inevitably, variable levels of redundancy in these many wireless components impact the frequency of failures [4].

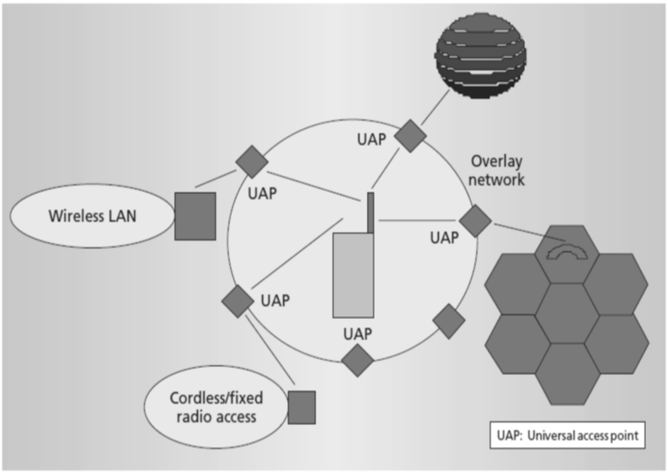

FIGURE 6. RELIABILITY IMPROVEMENT USING OVERLAY NETWORK [4].

There will be a natural emphasis on components that have the most influence on users and on boosting MTBF and reducing mean time to restore in order to reduce failure frequency and recover more quickly from errors. Customer impact disrupted services and high-level efforts for reducing mean time to restoration are all shown in Table 1.

Table 1. Wireless component failure impact and mitigation strategies [4]

Failure	Reasons	Services affected	No. of users affected	Time to fix	Ways to improve	Time to fix after improvements
Satellite	Hardware, cosmic factors	Paging, voice, data	1,000-10 million	Weeks to months	Hot standby or backup satellites	Minutes to hours
Mobile switching center	Hardware, software, operators	Voice, data	100,000	Hours to days	Redundant components, redundant power, smaller switches, Sonet ring, training	Seconds to minutes
Base station/ base station controller	Hardware, software, nature	Voice, data	1,000-20,000	Hours	Overlay base stations, redundant components, Sonet rings	Seconds to minutes
Home location register/visiting location register	Hardware, software	Voice, data, other services	100,000	Hours to days	Replicated databases, redundant components	Seconds to minutes
Device interface	Hardware	Voice, data, paging, other services	1	Hours to days	Multiple interfaces to access different wireless networks	Seconds to minutes

Computing the index for every outage occurrence provides a choice of options for averaging the effect of the outage across time or by aggregating the impact by causative components, such as a base station. Two types of services are included in the index:

• Registration blocking: customers are prevented from connecting to a wireless network because they are unable to register with the network from the outset; and

• Blocking of registered consumers' calls.

The ANSI wireless index may be somewhat perplexing, as seen in Table 1, which depicts the high-level strategies, affected services, and customer impact for reducing mean-time-to-restore. If a switch fails, most customers will be unable to utilize their services, and many connections between users will be broken. Initial registration and call delivery will be lost for cellular and PCS users.

Because many central office switches may be used as mobile switching centers if properly placed and controlled, they provide a high level of reliability. In mobile and wireless networks, database systems, base stations for mobile devices, and connectivity may all collapse at any time. Every network has a database that stores, maintains, and updates mobile users' location information. The server may mirror and duplicate databases over several networks to minimize the risk of failure. The use of redundant components can help to reduce base station failures, and as a result, the effect of a failed registration or call-blocking effort may be underestimated because of a lack of data. Wireless and PCS outage indices have been improved, but more improvements are required in this area, including the incorporation of traffic mobility assumptions [4],[11].

VII. MOBILE NETWORK SURVIVABILITY TECHNIQUE

In the event of a breakdown in any of the four levels of the network, the six fundamental actions outlined in Figure 7 may be used to restore the network:

Step 1 Detection: The relevant Operations Support System (OSS), controller, or network device detects the network failure.

Step 2 Notification: Using the control architecture, the failure of the network is communicated. In a centralized system, the failure must be reported to the central operations support system or controller, either directly through the network element or via another network monitoring operations support system.

Distributed control involves informing the other network components through the connections linking network elements or a separate data communications network. There are two simultaneous procedures that commence after the notification stage.

(i) Repair of the defective parts.

(ii) Affected traffic reconfiguration.

Most network survivability strategies can be implemented using these stages, however not all of them are required. Also keep in mind that some of the processes may be repeated.

Step 3(a) Fault Isolation: The term "fault isolation" refers to the process of pinpointing the location of a network problem.

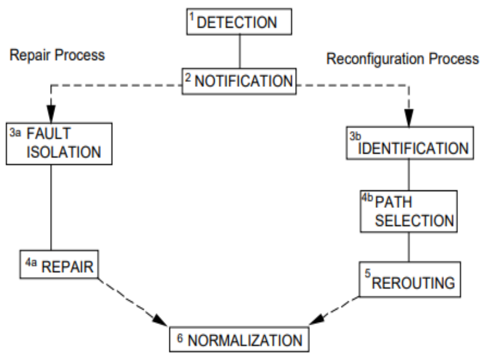

FIGURE 7. RELIABILITY NETWORK RESTORATION BASIC STEPS [11]

Step 3(b) Identification: The impacted requests are rerouted as part of the reconfiguration process.

Step 4(a) Repair: The repair procedure entails attempting to fix a network breakdown in order to restore network normalcy.

Step 4(b) Path Selection: Path selection is the process of looking up data or using an algorithm to choose an alternative path for each request that has to be diverted.

Step 5 Rerouting: rerouting is the shifting of the impacted demands to a new route.

Step 6 Normalization: Network normalization is the identification of the network's restoration to its pre-incident condition once a problem has been repaired. Rerouting impacted requests to new or original pathways might be part of this normalization [11].

SUMMARY

Telecommunications is a vast field that includes satellite, fiber-optics, microwave, mobile, and wireless networks, among others. Telecommunications systems have a long history of being designed with reliability in mind, and this design criterion is typically specified in terms of availability and reliability, so a contract called service level agreements (SLAs) is commonly used to specify a performance target. This paper has discussed mobile wireless telecommunication systems, architecture, components failure and mitigation, redundancy and survivability techniques.

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