The Integration of 5G Technology in Smart Cities: Challenges and Solutions

Almahdi Mosbah Almahdi Ejreaw *

Computer Technology Department, Higher Institute of Engineering Technologies Zliten, Libya

*Corresponding author: mahdiejreaw@gmail.com

Abstract:

Smart cities require advanced communication to share information and connect people from the cities and outside the cities. Today wireless technology is important to support mobility in communication. With advanced wireless communication adapted to smart cities, users can move and at the same time communicate with people in any corner around the cities. Speed and connectivity in communication represent the two important factors in smart cities communication systems. To have a high speed and stable connection in wireless communication technology, the 5G technology in communication systems is introduced. 5G technology not only can offer high speed and better connection in wireless communication but also offers more bandwidth to support large users. Besides that, 5G also supports the Internet of Things. This research paper presents a systematic review on the integration of 5G technology used in smart cities. The research will show the published papers on 5G technology used in smart cities from the year 2020 to 2023. Two databases will be used as references to support the reviews. The databases used are Google Scholar and Mendeley. At the end of the research, the challenges, and the solutions to improve the integration of 5G technology into the smart cities will be presented.

Keywords: 5G technology, smart cities, reviews of papers, challenges, solutions.

دمج تقنية 5G في المدن الذكية التحديات والحلول

المهدي مصباح المهدي الجريو*

قسم تقنيات الحاسوب، المعهد العالي للتقنيات الهندسية، زليتن، ليبيا

الملخص

تتطلب المدن الذكية اتصالات متقدمة لمشاركة المعلومات وربط الأشخاص من المدن وخارج المدن. تعد التكنولوجيا اللاسلكية اليوم مهمة لدعم التنقل في الاتصالات. ومن خلال الاتصالات اللاسلكية المتقدمة التي تم تكييفها مع المدن الذكية، يمكن للمستخدمين التحرك والتواصل في نفس الوقت مع الأشخاص في أي ركن حول المدن. تمثل السرعة والاتصال في الاتصالات العاملين المهمين في نظام اتصالات المدن الذكية. للحصول على اتصال عالي السرعة ومستقر في تكنولوجيا الاتصالات اللاسلكية، تم إدخال تقنية 5G في نظام الاتصالات. لا توفر تقنية 5G سرعة عالية واتصالاً أفضل في الاتصالات اللاسلكية فحسب، بل توفر أيضًا نطاقًا تردديًا أكبر لدعم المستخدمين الكبار. بالإضافة إلى ذلك، تدعم تقنية 5G أيضًا إنترنت الأشياء. تقدم هذه الورقة البحثية مراجعة منهجية حول تكامل تقنية 5G المستخدمة في المدن الذكية. سيعرض البحث الأبحاث المنشورة

حول تقنية 5G المستخدمة في المدن الذكية من عام 2020 إلى 2023. وسيتم استخدام قاعدتي بيانات كمراجع لدعم المراجعات. قواعد البيانات المستخدمة هي Google Scholar وMendeley. وفي نهاية البحث سيتم عرض التحديات والحلول لتحسين دمج تقنية 5G في المدن الذكية.

الكلمات المفتاحية: تقنية 5G، المدن الذكية، الدراسات السابقة، التحديات، الحلول.

Introduction

Smart cities are the cities that integrated with advanced technology to enhance the human living status [1]. The cities are equipped with sensors, machines, communication networks, and energy supplies that help to create the sensing and automation system in the cities. The words "sensing" and "automation" are the fundamental keywords to define smart cities. With "sensing" and "automation", the human living in the smart cities will become convenient. Example, automatic turn ON and OFF the light when people move in and move out from the building makes people convenient without manually turn ON and OFF the light. Similarly, with automatic temperature control the air conditioner in a room, the air conditioner will turn ON and OFF automatically. Another keyword to define the "smart" in the cities is Artificial Intelligence (AI). With the advent of AI, the cities will become smarter [2].

No matter how the cities turned into smart, the communications among the human in the cities are the most important one. Wireless internet communication now is preferred because it supports mobility of the human and reduces the complexity of wiring in the network. The evolution of wireless internet communication, especially used in cellular phones is developed from early digital 3 G until today is 5G [3]. Along with the evolutions, the speed and the bandwidth are the two factors that influence the connectivity of internet communication [4]. The speed is about how fast the user can access the internet network to send and receive the data. The bandwidth is about how many users the network can support. Over time, telecommunication engineers and researchers have come up with many ideas to improve the speed and bandwidth of wireless internet communication.

The Conceptual Framework

Figure 1 illustrates the evolution process of mobile wireless technology from 1 G to 5 G technology. Note that, the mobile wireless evolution begins to have internet start from 3 G onwards [5].
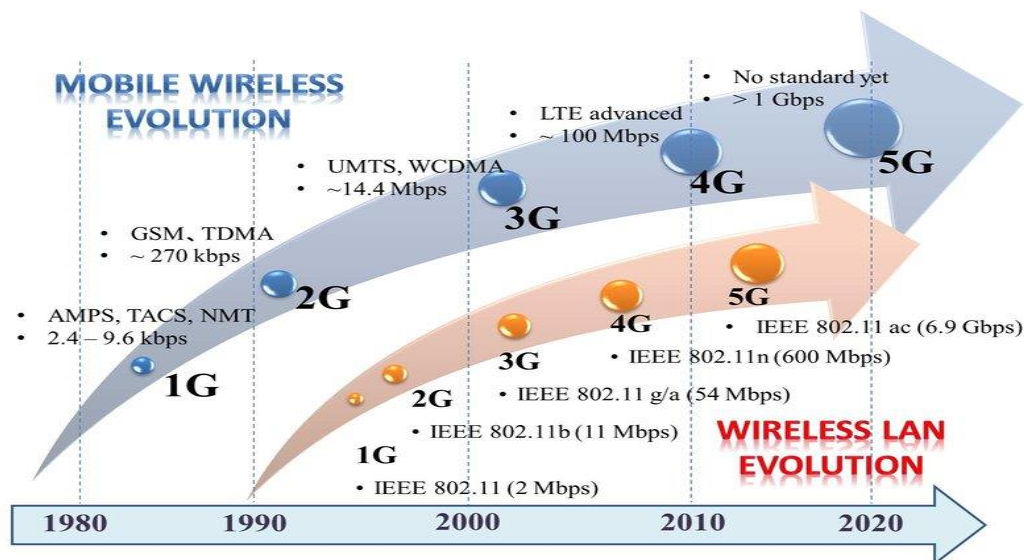
Figure 1 Evolution of mobile wireless communication [5]

The wireless internet access in 3 G is very limited. Such internet technology used is Wireless Application Protocol (WAP) [6]. The features of the WAP are micro browser build inside the cellphone, html employed in the phone, Java script used in the html page in the micro browser, using the web server similar to the existing web server, and the protocol layers used are session layer, transport layer, security layer, and application layer [7]. Because there is a limited bandwidth, which is 9.6 kbps and the speed is 56 kbps, so this causes the internet access is very slow and cause the problems in video and pictures communication.

After year 2010, the 4G had been introduced. The 4G has better bandwidth and internet speed. The 4G introduces Long-Term Evolution (LTE) to enhance the speed or data rate of in wireless internet communication. The speed of 4G with LTE technology is up to 1 Gbps [8]. The bandwidth that the 4G can support is up to 100 MHz. The 4G allows users fully accessed into internet in mobility mode. Users can use the cellphone just like using computer and laptop to access into internet. The browser used in 4G cellphone is similar to the one used in the laptop or

computer [9]. This means that 4G can supports Google, Yahoo, Bings, and other browsers appears in the phone. After year 2020, the new evolution of wireless technology called 5G was released [10]. The 5G wireless technology supports a bandwidth up to 400 MHz with speed or data rate is 1 Gbps (similar to the enhance 4G LTE data rate) [11].

5G Technology
The 5G technology is designed to improve the speed, reduce the latency, and increase the bandwidth so that it can support more users in wireless communication. There are many researches currently conducted to increase the speed of the 5G technology up to 20 Gbps. Apart from the speed and bandwidth difference between 5 G and 4 G, the 5 G also supports the Internet of Things (IoT) technology. This means that users can use their mobile phone to control the home appliances, monitor the environment, and enhance security via WiFi technology [12].
The 5G works together with Wireless Sensor Node (WSN) to form the IoT network in a small cell [13]. Because the 5G can be implemented into small from the cellular network, thus it can support many WSNs using WiFi technology. Below shows an example of IoT using 5G technology to support the automated guided vehicle, digital signage, and robotics.
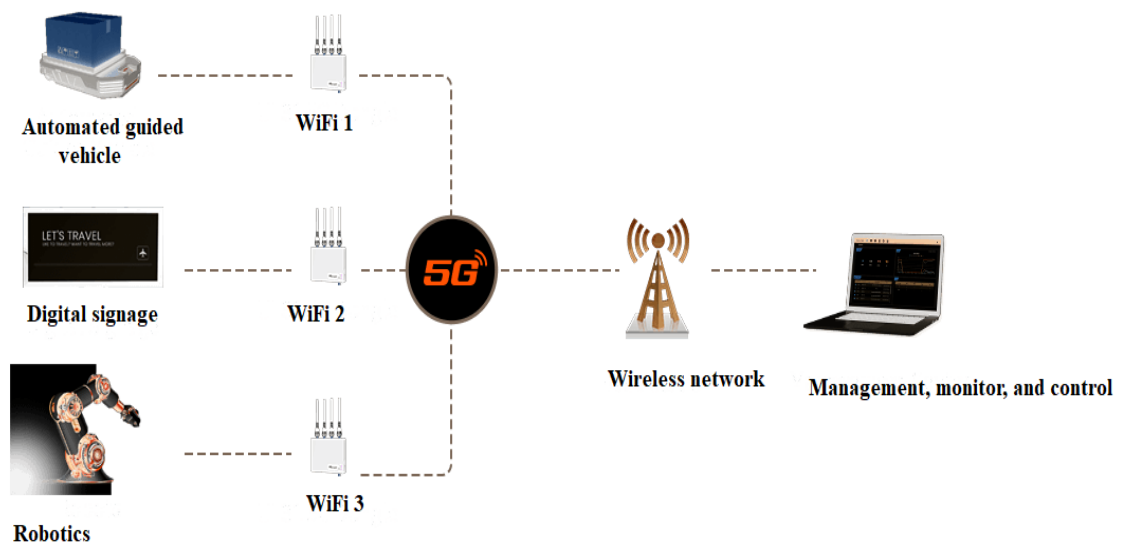

Figure 2 IoT technology using 5G network [14]

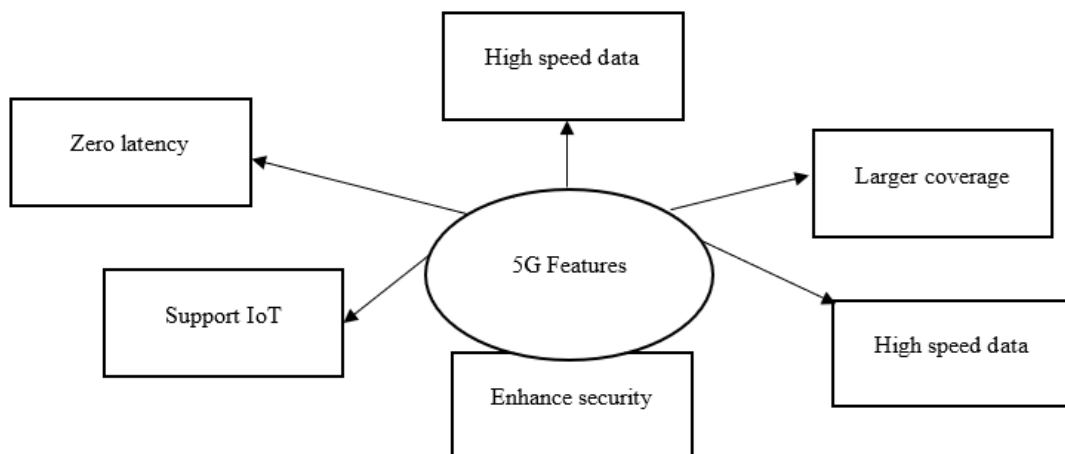The 5G technology features and technical details can be summarized as shown in Figure 3 and table 1.

Figure 3 The features of 5G technology [15]

Table 1 The 5G technology technical information [16]

SN.	Technical parameters	Values
1	Frequency	Low band: 450 MHz - 1 GHz
2	Frequency	Mid band: 1 GHz - 7 GHz
3	Frequency	High band: 24 GHz - 52 GHz
4	Bandwidth	50 MHz - 400 MHz
5	Data rate	1 Gbps - 20 Gbps
6	Modulation technique	Orthogonal Frequency Division Modulation (OFDM)
7	Uplink frequency	1.8 GHz
8	Downlink frequency	3.5 GHz

The Challenges of Integration of 5G Technology into Smart Cities

The integration of 5G technology into smart cities is a challenge and may face many problems. This section presents the general challenges of 5G technology integration with smart cities and the next section shows the reviews of 10 articles to summarize the challenges and solutions. The general challenges of 5G technology integration into the smart cities are [17]:

- Cost
- Health concern
- Functions provided by 5G communication devices
- Security
- Legislation

The cost is the main challenge for many current communication networks upgraded into 5 G networks. The 5 G communication devices are expensive. If one urban needs to convert into fully 5 G networks, there is a need of huge investment to do that. If the network is changed, the user mobile terminals also need to upgrade into 5 G. The problem is, not many users want to do that. Many of them still in the comfort zone of using 4 G communication devices. Unless the government and the network service providers have subsidized the 5 G communication devices and provide education to the people, then slowly the people will accept the change from 4 G communication devices into 5 G communication devices. Besides the cost of the 5 G network is high, the charging rate of using 5 G technology is also high. Not many people like to pay high for new technology if the current technology works well.

The next challenge is the health concern. As mentioned before, the cell size of the 5G can makes small compared to ordinary cellular coverage size. If more cells are used, this means the radio waves will cover more areas. The frequency transmitted by the radio tower is concerned by many people because people believed that the radio frequency can affects the health. There is a study on the frequency of 5G that can affect health [18]. The study had showed that when the frequency of the 5G reaches millimeter wave range, the electromagnetic waves absorption to the biological body will over the Standard Absorption Rate (SAR). This can cause skin cancer and disease [19]. The radiation of the 5G wave is continuous, therefore the health of the people who live nearby the 5G radio tower will be affected much compared to the people who live far from the 5G radio tower.

Another challenge is the function provided by the 5G technology. As we know currently many people use social medias the most in the cellphone for communication. Some people use browsers on the phone to look for information. These are the current functions provided by the 4G technology and work well in all the 4G phones. The 5G also supports the social medias communication but added with IoT technology. But the problem is, there are not many people use the IoT function provided by the 5G communication devices. This is because there is still lacking of IoT devices in the market. Even the 5G has IoT function but cannot be used because not many appliances in the buildings or at home have IoT functions. This gives the "waste" impression to many people who use 5G communication devices. Also, many people have feels that 5G internet access speed is no different from 4G internet access speed. This may be because people carry 4G communication devices do not need extreme high speed data rate and they just use voice and picture communication most of the time.

The next challenge is the security in the 5G technology system. The 4G already have good security with good encryption technology. The 5G perhaps needs to focus on security systems to avoid scammers. This is because currently there are many scammers who uses advanced technology to scam people. Such technologies used by scammers become a challenge to the 5G technology. The 5G also faces a challenge to secure the IoT data. This still in research and development [20]. Another security enhancement used by 5G technology is the blockchain [21]. Again, the challenge faced by the 5G technology is, how reliable blockchain is when comes to online transaction. Does this blockchain security compatible with normal or other security systems used by the banks? The security enhancement for the 5G has to be improved so that it will be totally different from the 4G. With the new feature added to the 5G security system like scammer detection, then this might attract more people used 5G communication devices instead of 4G communication devices.

For the legislation, it depends on the rules and regulations fixed by the Federal Communications Commission (FCC). The 5G so far is legal to use because the frequency, bandwidth, and data rate are defined by FCC in standard. Not only that, IEEE also has defined the 5G frequency and bandwidth in standard [22]. According to IEEE, the standard for 5G is IEEE 802.11 WG. A more detail of this can be found in [23] and [24]. The IEEE and FCC have to define the standard for 5G because it is worry of illegal use of 5G spectrum. Many frequencies resources have been occupied and used for other applications like in military, police communications, and so on. Therefore, when the countries develop the 5G technology, the spectrum or bandwidth must be defined carefully in order not to crash for other applications.

The Challenges of Integration of 5G Technology into Smart Cities
from Literature Reviews and Solutions. This section presents the reviews of challenges for the 5G technology integrated into smart cities and solutions suggested to overcome the challenges. There are 10 papers selected to review the challenges and these 10 papers are the most recently published papers from year 2020 to 2023. The reviewed papers are explained below:

Paper 1: The Role of 5G Technologies: Challenges in Smart Cities and Intelligent Transportation Systems by Leonardo Guevara and Fernando Auat Cheein, 2020 [25]

This paper discusses the 5G technologies implemented in the vehicle used in smart cities. The challenges presented are the technical implementation of the autonomous and semi-autonomous vehicles using 5G, economic, and legislation. The autonomous is the one facing the most challenge. This is because the technology used is automatic drives of vehicle under the control of 5G technology. The vehicle should extremely be safe on the road and the 5G technology must integrated with GPS as well as internet networks to guide the vehicle self-drive in the cities. With this technology, it leads to the economy of production of the autonomous vehicles and the legislation used of such vehicles on the road.

Paper 2: IoT - Security & Challenges of 5G Network in Smart Cities by Devasis Pradhan, Hla Myo Tun, and Ajit Kumar Dash, 2022 [26]

The main challenges discussed in this paper are the security, protection, and trust issues in 5G networks used in smart cities. The IoT is the one proposed in the paper, but there is a security issue faced by the IoT. The security is, IoT data from a single WSN is very small in size and not important. If security is implemented into this IoT data, it may be considered a "waste". However, with more and more WSN appearing in the network, protection of IoT data may be needed depending on how significant the data send by the WSN. The IoT data could be also attacked by the malware when the data is stored in the cloud. As a matter of fact, the security of the IoT should be implemented in the cloud or in the data transmission? This becomes a challenge to most of the wireless 5G engineers.

Paper 3: 5G Networks Towards Smart and Sustainable Cities: A Review of Recent Developments, Applications and Future Perspectives by Muhammad J. Shehab, Ihab Kassem, Adeeb A. Kutty, Nuri Onat, Tamer Khattab, and Murat Kucukvar, 2021 [27]

This paper has shown the literature reviews of 5G technologies employed in sustainable smart cities. The challenges proposed are environment, social, economic dimensions, sustainability, cost, health, and safety. The focus of the discussion is on the sustainability of the 5G technology used in smart cities. The results showed that in the past literature reviews, there were 42% discussed on environmental affect by the 5G, 37% interested on economic, and the remaining is about the cost of implementing the 5G into smart cities.

Paper 4: Future Trends and Current State of Smart City Concepts: A Survey by Ayca kirimtat, Ondrei Krejcar, Attila Kertesz, and M. Fatih Tasgetiren, 2020 [28]

This paper has presents many "smarts" in the development of smart cities. The suggested challenges in smart cities when using 5G networks are smart coverage, smart power management, smart environment, and smart home appliances. According to the paper, there are still many gaps for the 5G technology implemented into the smart cities. The floating smart cities was discussed in the paper. The paper suggested that all the challenges mentioned above should be smart in giving good living styles for the mankind.

Paper 5: A Survey on 5G and LPWAN-IoT for Improved Smart Cities and Remote Area Applications: From the Aspect of Architecture and Security by Emmanuel Utochukwu Ogbodo, Adnan M. Abu-Mahfouz, and Anish M. Kurien, 2022 [29]

The LPWAN-IoT facing the big challenges on geographical area in the smart cities, the power consumption, security, and reliability. The LPWAN-IoT using low power consumption in communication. It also uses 5G technology. When this PLWAN-IoT is implemented in the high-density areas around the smart cities, the signal may be affected by the obstacles around the high-density area. Power management becomes a challenge to the LPWAN-IoT technology. The next challenge studied is security and reliability. The LPWAN-IoT is mainly for sensors' data and this may not require security. However, in future the data volume may be increased, and the security becomes significant.

Paper 6: Integration of IoT-Enabled Technologies and Artificial Intelligence (AI) for Smart City Scenario: Recent Advancements and Future Trends by Md Eshrat E. Alahi, Arsanchai Sukkuea, Fahmida Wazed Tina, Anindya Nag, Wattanapong Kurdthongmee, Korakot Suwannarat, and Subhas Chandra Mukhopadhya, 2023 [30]

This paper shows the challenges of AI technology integrated into smart city with 5G IoT technology. With the advent of AI, the smart city become more automation with fully controlled by the machine. This required a smart IoT technology in the 5G network. The speed and the number of WSNs supported by the IoT becomes an issue. But with the AI, it is able to handle and manage the data flows in the network. The biggest challenge discussed is, how AI can helps to improve the efficiency of IoT technology used smart city.

Paper 7: Blockchain for 5G and beyond networks: A state of the art survey by Dinh C. Nguyen, Pubudu N. Pathirana, Ming Ding, and Aruna Seneviratne, 2020 [31]

This paper shows the blockchain security challenges in the 5G network. The use of blockchain normally in banking transactions. The issue with blockchain implemented in the 5G network whether can gives reliability or not still needs to be concerned by engineers and scientists. With the blockchain technology, it enables the 5G network integrated with cloud computing and secure the communications in the entire internet network. The question arises is, will the blockchain is necessary for the 5G network? If yes, why current security not eligible for the 5G network?

Paper 8: Injection attack detection using machine learning for smart IoT applications by Tarek Gaber, Amir El-Ghamry, and Aboul Ella Hassanien, 2022 [32]

This paper is discussing the security of using IoT in smart city. The proposed security system is called injection attack detection for the IoT network. This technique of injection of attack facing two challenges in implementation. One is constant removal and second one is recursive feature elimination. Because the technique is difficult to implement, thus a machine learning is suggested.

Paper 9: Blockchain envisioned UAV networks: Challenges, solutions, and comparisons by Parimal Mehta, Rajesh Gupta, and Sudeep Tanwar, 2020 [33]

This paper presents the security issue in 5G enabled UAV network which works in smart city. The UAV is a kind of drone that normally used by military and polices to monitor commotions in a certain area. The UAV can form a network in the sky if high quantity of them exists. UAV also can also communicate on each other when performing a certain task. Thus, the paper suggests using blockchain technology to secure the communication. The challenge is, the UAV must maintain a constant distance for secure communications.

Paper 10: Using 5G in smart cities: A systematic mapping study by Chen Yang, Peng Liang, Liming Fu, Guorui Cui, and Feng Teng, 2022 [34]

This paper shows the 5G technology implementation in the smart cities with challenges mainly on complex context, requirements, and network development using 5G technology. The challenges represent the problems where the engineers have to think of for future improvements of the network. It is agreeing that the 5G network is very complex. The possibility of upgrade the 4G network into 5G is very low. Thus, the network service providers have to invest certain amount of money to re-build the 5G network.

Results

From the latest 10 articles collected and reviewed, the results of observations on the challenges topics proposed can be summarized as shown in Table 2.

Table 2 The results of challenges on the topics of 5G integrated into smart cities based on 10 articles.

Paper No.	Types of challenges	Proposed Solutions
1	Economic and legislation	Government intervention
2	Security	Blockchain technology
3	Environment, social, economic dimensions, sustainability, cost, health, and safety	Government intervention
4	Smart coverage, smart power management, smart environment, and smart home appliances	More researches have to do on feasibility of implementation
5	LPWAN-IoT implementation	Implement in low dense area
6	AI technology integration into smart city with 5G	Implement in a small area in the smart city
7	Security	Blockchain technology
8	Security	Blockchain technology
9	Security	Blockchain technology
10	Complexity of the 5G network	More researches have to do on reducing the complexity of the 5G network
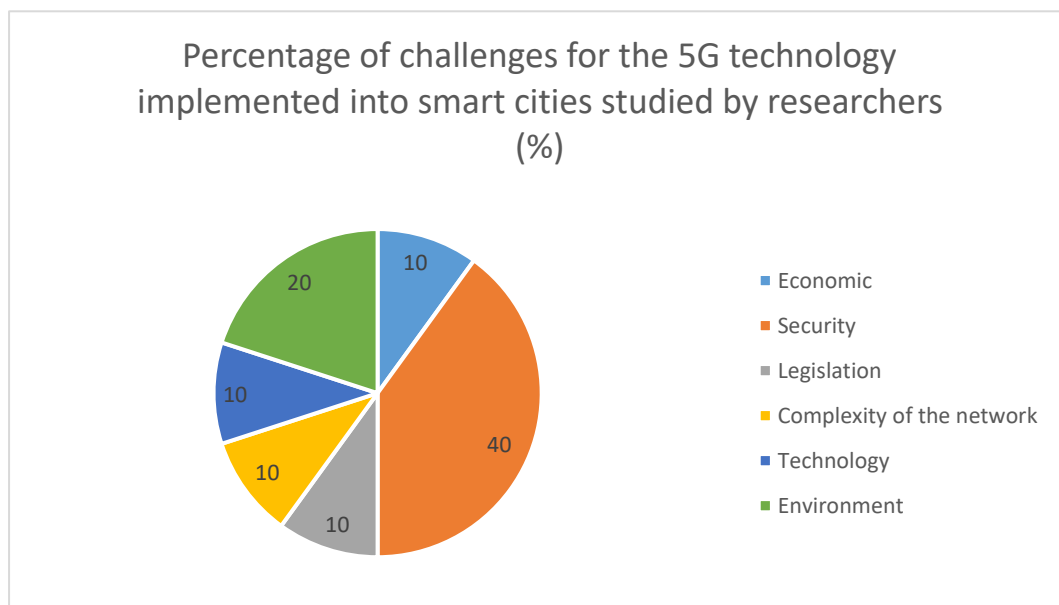
Figure 4 Types of challenges focused by researchers.

From the results shown in table 2 and Figure 4, it is seen that security challenge is the most concerned topic studied by many researchers on the topic of 5G technology integrated into smart cities. Security challenge topic reviewed in this research is 40%. Although the blockchain keyword appears many times in 5G technology studied, this can conclude that security is the most important topic in the design and development of 5G communication system. There are also 20% research concerned about the environment when 5G technology is deployed in the smart cities. The research believed that deploying 5G transmitter and other equipment in the smart cities will need to destroy some of the forest in the environment. This indirectly damages the habitat of the animals in the forest.

Conclusion

In conclusion, the 5G technology integrate into the smart cities facing the great challenge in security. This topic is still in research and there are many researches discussed on it in theory only. Until today, there has been no technical method used to implement the block chain into the 5G security system, especially on the IoT technology. It is believed that there is a need a set of protocol to implement the blockchain into the 5G technology. Overall, the proposed solution can be suggested to improve the security using blockchain is to get more research works on that topic. Perhaps the algorithm and simulation can be proposed to study the blockchain implementation into the 5G network to secure the communication.

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