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Integration of D2D, Network Slicing, and MEC in 5G Cellular Networks: Survey and Challenges

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ABSTRACT With the tremendous demand for connectivity anywhere and anytime, existing network architectures should be modified. To cope with the challenges that arise due to the increasing flood of devices/users and a diverse range of application requirements, new technologies and concepts must be integrated to enable their benefits. Service providers and business companies are looking for new areas of research to enhance overall system performance. This article gives a detailed survey about the recent 5G technologies, the solutions they provide, and the effect caused by their addition to current cellular networks. It is based on the three most important 5G concepts: Device to Device (D2D), Network Slicing (NS), and Mobile Edge Computing (MEC). This study proposes to design the future 5G networks by the integration of all three technologies. It is believed that spectrum efficiency, energy efficiency, and overall throughput will be greatly improved by using D2D. The system delay and computational load will be reduced as tasks will be handled by edge routers located at the base stations. Thus offloading the core network and the system capital expenses and operational expenses will be reduced significantly by slicing the network.

INDEX TERMS 5G cellular networks, D2D communication, mobile edge computing, network slicing.

I. INTRODUCTION

Next big thing in the future is 5G technology, which is expected to grow three-folds by 2025 with applications ranging from robots, health services automation, smart agriculture machinery, and industrial control systems [1]. For 2G it took nearly 20 years from its deployment in 1991 to peak in 2011, and 3G recently peaked in 2016, 15 years from its original deployment. 4G is expected to peak in mobile subscriptions by 2022, 12 years from its original deployment. However, what differentiates it from other mobile generations is its rate of growth, as the 2G and 3G network's rate of decline increases. By 2020, the 2G, 3G, and 4G distributions were roughly 35.5%, 37.5% and 25% respectively, and by 2024 most of the world is anticipated to shift to 5G, covering almost 60% of the network space [2]. This is due to the increasing demand for faster data, enormous devices, and various global initiatives to increase connectivity around the planet. Another reason for the massive adoption of 4G will be its backward compatibility in the future to help transition users to 5G. New mobile chips will allow 4G, 5G, and Wi-Fi to work together in unison to provide consistent connectivity wherever you are. If for example, 5G beamforming loses line-of-sight connection with your device due to some unforeseen obstacle, your device will be able to switch to a 4G network and back again when a connection with the 5G small cell is re-established, without any noticeable drop in service [1]. As you can see, 4G, more specifically LTE-A Pro is an integral part of the seamless transition to 5G. With the improvements in bandwidth and energy consumption that LTE-A Pro introduces and 5G will expand upon, more wireless subscribers coming online, there will be more competitive rates for larger data plans [3]. These gigabit level speeds, low latencies, and low costs will open many use cases for 5G such

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as home routers with comparable speeds to Wi-Fi, seamlessly integrated augmented reality devices, and much more. The massive increase in the adoption of new services like mobile data downloading, sharing, and streaming has resulted in the worldwide rapid growth of mobile subscriptions. It is expected that by 2026, the mobile subscription will reach 8.8 billion with approx. 91% of them being mobile broadband. At the end of 2020, the global smartphone subscription was almost 6.1 billion, which is expected to be 7.5 billion by 2026 [4]. The cloud computation and network virtualization market in 5G is forecasted to be the value of USD 7.56 billion by 2025 [5].

In the future, applications may have variable needs in terms of data rate, delay, and reliability which is not possible with the same physical network infrastructure. NS is the concept that will create separate dedicated slices on the cloud and will help the users to utilize the network based on their demands. Like the scenario in which the person using online gaming requires more speed and less delay than the person using Facebook or WhatsApp. Crowded events like in musical concerts or cricket matches, there are a lot of people in a particular area who are sharing their live video or data with heavy applications so, they will benefit from network slicing and 5G. The organizers of the event must pay for a slice of the network that will boost the network capacity and internet speed-enhancing audiences' online experience [3]. Global System of Mobile-Communications (GSMA), in their research [6] stated that 5G network slicing can unlock the business opportunities to the estimate of $300 billion amount by the year 2025. Still, the important research question is how the network slicing will meet up the demands of various verticals across 5G systems.

MEC has emerged as a promising concept that overcomes the burden of central cloud servers. This involves providing network storage, computing, and resources capabilities at the mobile edge nodes. Due to closer deployment to the user, the latency can be reduced significantly. This will enable the benefits of high bandwidth, delay-sensitive, load sharing, socially aware, and caching applications. The core and backhaul network offloading is a very important feature in MEC [7]. Each base station is equipped with an edge server so that it can perform all the computing tasks locally for proximity services in end users. Due to the dynamic traffic management requirements, the European Telecommunications Standards Institute (ETSI) introduces the concept of network virtualization and cloud computing facilities [8]. However, in the future MEC and network virtualization integration is expected to deliver network capabilities more efficiently and rapidly.

D2D concept enables the direct connection between devices in a cellular network without involving the base station or central fixed/wireless infrastructure [9]. The communication can be between two devices or it can be among multiple devices where the role of D2D is as a relay to provide good signal strength to the users present at the edge of the network. The prospective benefits that can be achieved through D2D are better spectrum utility, energy efficiency, less delay, improving system throughput, and battery saving [10]. System overall coverage and capacity can be enhanced significantly resulting in good economic and business gains.

This detailed research study is based on the comprehensive overview of the aforementioned concepts related to 5G, the history of research work in these areas separately, and the aspect of different benefits achieved by the combination of these different technologies. Finally the discussion on challenges, possible solutions and future trends.

II. CONTRIBUTIONS AND SCOPE

5G technology is believed to revolutionize the completely different era of network designs and interfaces with a diverse range of applications. The challenges and hurdles in shifting to new technologies remain open issues. Many researchers, different government organizations, and industrial collaborations are striving their best to make this possible. To completely understand the vision of 5G, its various new technologies need to be investigated in detail. Table 1 provides the summary and comparison of previous survey works done in this area and their short-comings compared to the proposed work.

TABLE 1. Detail of Surveys.

Ref.	D2D	NS	MEC	Model
[7]	No	No	Yes	5G
[11]	Yes	No	No	5G
[12]	Yes	No	No	5G
[13]	No	Yes	No	5G
[14]	No	Yes	Yes	5G
[15]	Yes	Yes	No	5G
[16]	Yes	No	No	General
[17]	No	Yes	No	5G
[18]	No	No	Yes	General
[19]	No	No	Yes	5G
[20]	No	No	Yes	General
[21]	No	No	Yes	5G
[22]	No	Yes	Yes	5G
[23]	No	Yes	Yes	General
[24]	Yes	No	Yes	5G
[25]	No	No	Yes	5G
[26]	No	Yes	No	General
[Proposed]	Yes	Yes	Yes	5G

Over the past few years, a lot of work has been done in the field of 5G cellular networks. The existing literature work can be broadly categorized as follow: (1) Conventional 5G cellular networks, (2) D2D based 5G cellular networks, (3) Network slicing based 5G cellular networks, (4) Mobile edge and cloud computing 5G cellular networks, (5) D2D and MEC based 5G cellular networks, (6) D2D based

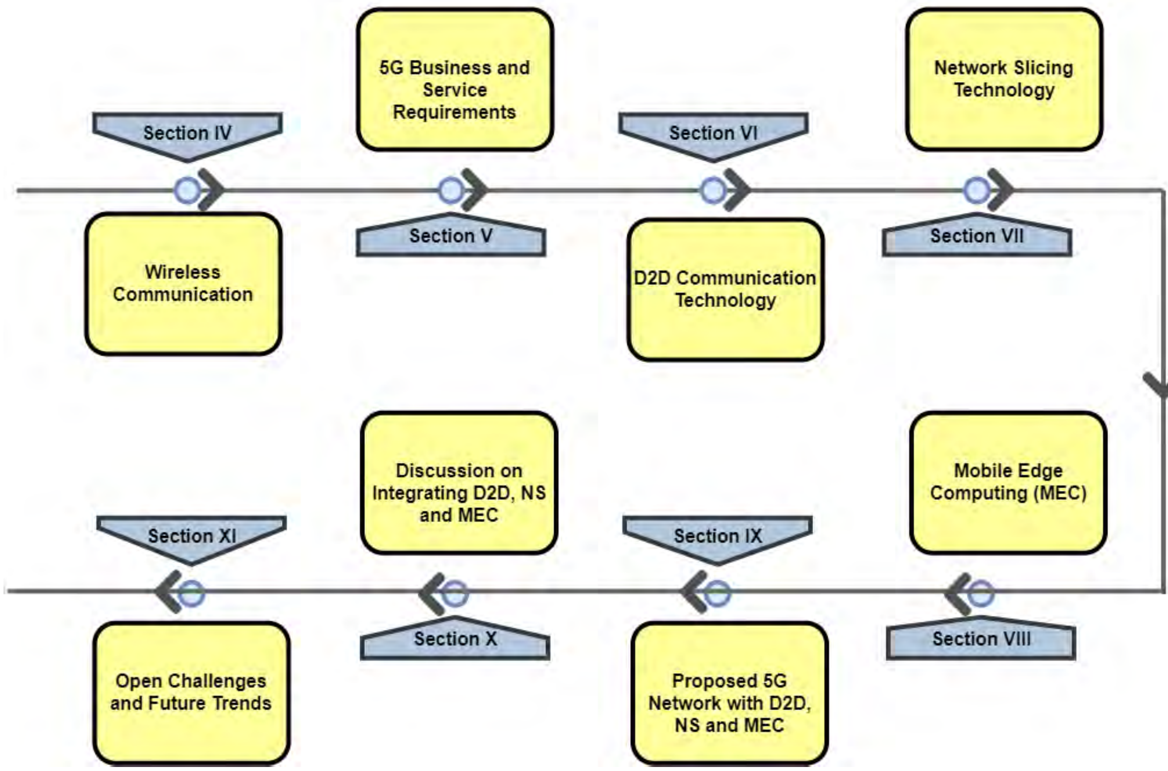

FIGURE 1. Structure of Paper.

virtualized 5G cellular networks, (7) Network slicing and MEC based 5G cellular networks. Extensive studies and techniques were considered for improving their performances but these researches were limited in one way or the other. Some of them presented limited evaluation and standardization policies, lacking detailed explanations of current research works and state of the art challenges. Similarly, no concrete study proposed the aspect of combining the above-mentioned technologies in a single work.

To the best of the author's knowledge, there is no existing work that covers the integration of D2D, NS, and MEC with 5G cellular networks and investigates the effect of 5G network architecture transformation and benefits. The scope of this study is to design the future next generations cellular networks in such a way that they can support a massive number of devices with an enormous range of customized applications in the least possible time without overloading the infrastructure and core network. This will result in enjoying a real-time gaming experience, critical emergency services, high speed, reliable remote applications, and many more with reduced cost.

The combination of technologies like network virtualization and 5G permit to construct end-to-end network design by partitioning the shared physical infrastructure. Due to the expected increase in the number of connected devices, it becomes necessary to incorporate network slicing with edge computing and D2D to accommodate the demand of the devices. This will build new network designs and realizations in the existing 5G networks.

III. STRUCTURE AND ORGANIZATION

Fig. 1 represents the overview of the areas discussed in this work. We have provided the comprehensive details on the research work done in three major 5G technologies i.e, D2D, NS and MEC. Then the we have proposed the future architecture, discussion, challenges and future recommendations by integrating all of them. Section IV gives the brief summary of mobile communication technologies (1G to 5G). Section V is related to 5G business and service requirements with all the features, 5G used cases, and research challenges. Section VI is about D2D communication technology, its performance characteristics, the hierarchy, configuration, classification, and application scenarios. The detailed research work done in D2D resource management and optimization. Section VII discusses the work done in 5G NS technology, business perspectives, solutions, phases, and different layers. The research work in resource management with 5G NS and with D2D using NS. Section VIII is on MEC and research done in D2D with MEC. Section IX provides the architecture of the proposed model and explanation of its each layer. Section X gives a detailed discussion about the integration of D2D, NS and MEC. Section XI is related to open research challenges and future trends. and finally Section XII is about the conclusion.

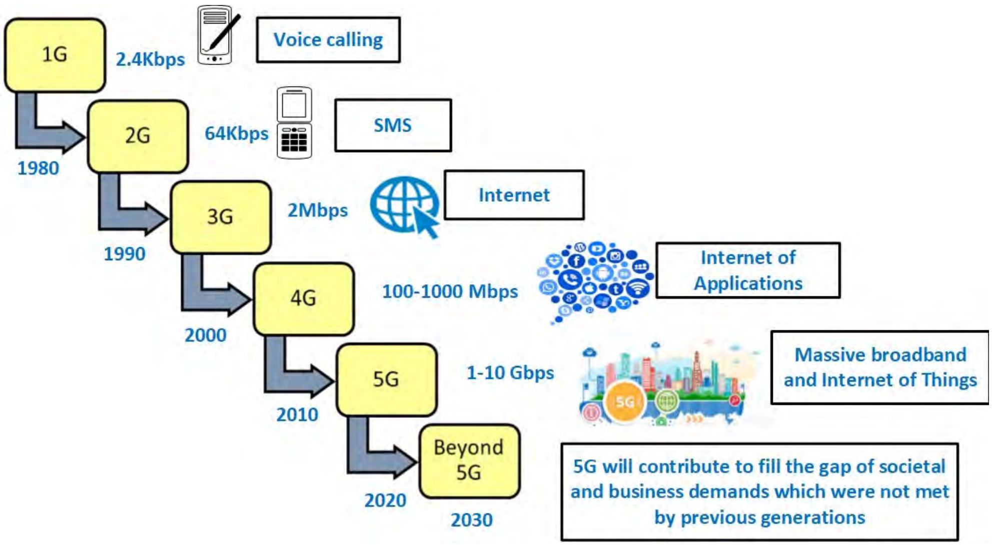

FIGURE 2. Timeline of Mobile communication generations [27].

IV. WIRELESS COMMUNICATION

Around the world, telecommunication companies and service providers have been struggling to propose the latest solutions for meeting the increasing demands of mobile data from business users and household customers. The beginning of the mobile wireless industry can be dated back to 1970. The cellular system became popular even more than was expected in the 1960s and 1970s. By the 1990s, this idea experienced tremendous growth as the number of mobile subscribers increased, and by 2010, there were four times extra mobile subscribers than the landlines.

Wireless communication technology has emerged because it was difficult to install wired links over long distances between the transmitter and the receiver. In 1895, the Italian scientist named Marconi was the first one to transmit the wireless signals through radio waves at a distance of 3.2 Km by using Morse code [27]. It was a break-through in the history of science when researchers and scientists started using radio frequency waves for communication. They started developing new devices that do not involve wired links and should be capable of providing mobility. This instant, widespread triumph of wireless communication concepts resulted in the evolution and improvement of standards due to diverse range of applications [28]. Wireless technology is beneficial in many ways:

1) Greater Efficiency
2) Less Hardware
3) More Flexibility
4) Low Cost

A. MOBILE COMMUNICATION (1G TO 5G)

The evolution of different mobile communication generations from 1G to 5G with time are in Fig 2.

In 1970, Martin Cooper developed the 1G mobile phone that provided two-way communication [27]. This generation used analog signals and the major disadvantage was they were not able to cover long-distance due to signal attenuation [29].

2G allowed voice calls, short text messages and emails with digital technology. An example of 2G was (GSM) group special module whose name changed to Global System for Mobile Communication later with the speed of 14.4kbps to 64kbps [30]. 2G provided low internet speed with limited services support.

To provide better data rate, 2.5G named as General Packet Radio Service (GPRS) and 2.75G called as Enhanced Data-rate for GSM Evolution (EDGE) came in [29]. For GPRS, the data rate was 56 to 64 kbps, and for EDGE, it was around 170 kbps.

3G first emerged in 2001. It provided us with a speed of almost 384 kbps. The first 3G network was introduced commercially by the end of 2001 with WCDMA [31]. 3G became so popular that the number of subscribers reaches 295 Million at the end of 2007. 3G not only allowed for calls and text messages but also provided access to high-speed internet ranging from 200kbps to a few megabits per second.

With the emergence of the diverse range of services required by various applications, the researchers in 2009 proposed the technique on the benefits of multiple services (both real-time and non-real-time) introduced in CDMA based 3G networks [32]. The work suggested user's versatile quality of service (QoS) needs and power consumption control using cooperative game theory methods and finds the user's degree of satisfaction. Such a framework helped to evaluate various 3G technologies like CDMA and WLAN, their power, resource allocation, and QoS expectations. 3G called as Universal Mobile Telecommunications System (UMTS) introduced video calling for the first time. Then, smartphones became famous worldwide, with multimedia, games, health services, and a whole new social media experience [31].

3G technology was upgraded for more speed by few enhancements. The first was 3.5G with a very high data rate of 2Mbps and the second was 3.75G [28]. Later, it evolved into an improved 3.9G system known as Long Term Evolution (LTE). The drawbacks of 3G were expensive infrastructure, costly spectrum demand, and expensive 3G smartphones.

The wireless communication technology named in 4G is LTE and LTE advanced. They provided very high-speed internet ranging from some megabits per second to gigabits per second. It was started in September 2008 with enhanced support for multimedia applications.The most important benefit of this was its compatibility with the previous generations [33].

The Fifth generation (5G) of mobile communication enables faster access to the network with low latency and high reliability. In this way, the data reaches the server with less delay and making possible the connection of many devices to the mobile network. It can provide a very high data rate, minimum transmission delay, more capacity, and the flexibility to add new services and features. The most important among them will be 100 times better capacity and enhanced internet speed than 4G [31], [33]. For example, 3G would take almost 15 hours to download a video of one hour, 4G would take about 5 minutes, but with 5G, it will be only 2 seconds. The response time in 4G was 50 milliseconds, which is now 400 times less in 5G having the value of almost one millisecond quicker than the blink of a human eye. Reducing transmission delay is very critical. Autonomous cars require a constant data connection with high speed and minimum delay [34].

Fig. 3 shows the comparison of data rates for mobile communication generations.

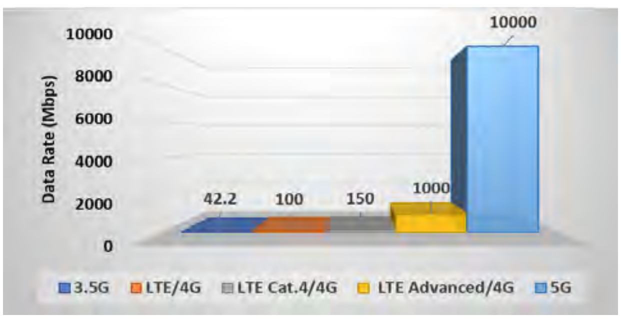

FIGURE 3. Data Rate comparison of Mobile technologies.

V. 5G BUSINESS AND SERVICE REQUIREMENTS

As 5G is garnering more attention, service providers are scrambling to buy more spectrum space and beginning to roll out more infrastructure as fast as possible. Over the coming years, there will be improvements in latency and speed. Currently, the LTE-A speed average around 50 to 100 megabits per second mostly. By the near future, at a conservative rate of growth of small cell deployments, massive MIMO arrays, and other technologies, the speed should average in the range of 500 megabits per second to 1 gigabit per second with latencies to about 25-millisecond range [35]. For the average mobile data consumer, these speeds will be more than enough for a very long time, and the bandwidth should be large enough to support all the new devices that come to market.

A. IMPORTANT 5G USE CASES

5G requirements and standards were defined by the governing bodies ITU and 3GPP [36], [37]. 5G telecommunication networks will comply with user's various QoS requirements. There are three major 5G used cases, proposed by standard organizations [38] shown in Fig. 4.

- enhanced-Mobile-Broadband (eMBB)
- massive-Machine-Type-Communication (mMTC)
- ultra-Reliable-Low-Latency-Communication (URLLC)

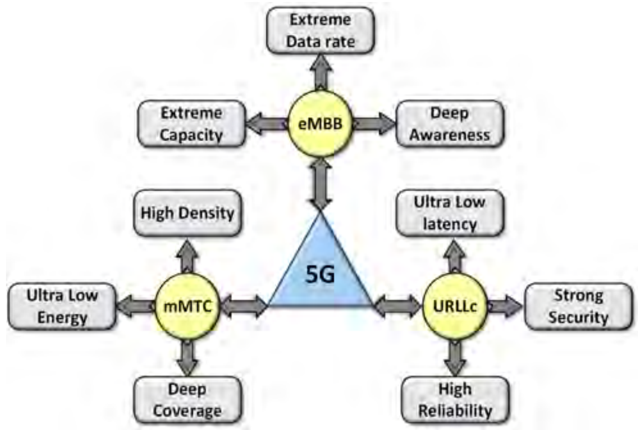

FIGURE 4. 5G Use Case scenarios (IMT-2020 and beyond) [39].

1) eMBB (ENHANCED MOBILE Broadband)

This case provides a very high-speed data rate and capacity even at the cell edge with faster connections setup and coverage. Examples include high-quality video downloading, 3D gaming, live video streaming, and many other intensive image and data scenarios to provide the required performance like virtual reality and high accuracy medical applications [38]. Nokia Communication published a report which predicted that from 2020 to 2030, there might be a drastic increase in traffic requirements up to 10,000 times over mobile broadband applications.

2) mMTC (MASSIVE MACHINE TYPE Communication)

5G based IoT scenario with tens of billions of attached devices and sensors. They support a large number of small data packets-based applications like smart home automation, intelligent wearables such as fitness bands, smart appliances, and many more that will improve with the advancement of 5G with time.

3) uRLLC (ULTRA-RELIABLE LOW LATENCY Communication)

For highly crucial applications that require rapid communications with minimum latency. Examples are remote surgery and autonomous vehicular communications like self-driving cars that respond promptly to avoid accidents and any casualties [39]. The data should be highly reliable for 5G industrial and medical applications using the emerging concepts of machine learning and artificial intelligence for analysis.

It is reported [40] that by 2022, out of the 29 billion connected devices, the majority of them will be machine-to-machine devices. 5G promises to provide users QoS requirements with various scenarios like high data rate, reliability, and minimum delay [41]. There are cases that require wide-area coverage, the network should provide users with the desired speed at cell edges. In the case, where a huge number of low-power devices require reliable connections, the networks must be capable of connecting millions of devices with low power constraint low cost per device. Very high reliability and low latency are needed for the efficient performance of real-time applications [39].

B. 5G KEY FEATURES

There are various features of 5G that make it unique and widespread.

- Date Rate: upto 10Gbps
- Speed: 10 to 100x better
- Latency: Less than 1-millisecond
- Bandwidth: 1000x more
- Devices: upto 100x more
- Availability: 99.999%
- Coverage: 100%
- Energy Usage: 90% reduction
- Battery Life: upto 10 years

VI. D2D COMMUNICATION TECHNOLOGY

In cellular networks, the base stations (BS) is involved in the connection set-up between two user equipment (UE). For example, UE sends its data to BS using uplink (UL) resources, and then the BS redirects the data to a corresponding receiver using downlink (DL) resources. D2D communication refers to a radio technology that allows devices to directly exchange data without the use of a BS or its core network [42]. Fig. 5 clearly explains the idea of a direct communication link.

FIGURE 5. **Communication links.**

The Third Generation Partnership Project (3GPP) has investigated the proximity service (ProSe) communication under the control of cellular networks. 3GPP group divided ProSe communication into two parts proximity discovery and direct D2D communication [43], [44]. Details of the conceptual framework for incorporating D2D under the existing networks were discussed in [45], [46], where authors presented the concepts of device discovery, mode switching, user scheduling, and resources allocation for D2D based cellular networks.

A. PERFORMANCE METRICS FOR D2D COMMUNICATION

The D2D performance criterion can improve the overall network throughput by using efficient and intelligent resource optimization techniques. Most important among them are:

- Throughput
- Spectrum Efficiency
- Energy Efficiency
- Capacity
- Secrecy Rate
- Latency

B. HIERARCHY OF D2D AREAS

Fig.6 depicts the complete picture of different areas of research and their flow in D2D based communication.

C. CONFIGURATION OF D2D COMMUNICATION

There are three different ways for D2D configuration [47].

1) NETWORK CONTROLLED D2D COMMUNICATION

In this scenario, the BS fully controls D2D communication (e.g. control signal, resources management, and discovering/establishing the connection). The centralized control results in efficient interference management and resource allocation. However, this configuration also causes high signaling overhead, wherein the number of D2D becomes large, and spectral efficiency (SE) is reduced [48].

2) AUTONOMOUS D2D COMMUNICATION

This scenario is like cognitive radio in which BS has no control over D2D users. Instead, D2D users leverage empty holes in the spectrum and sense a surrounding environment for obtaining channel state information (CSI), interference, and cellular user information. Although this method can avoid signaling overhead and time delay, communication security can be a potential issue. This configuration also causes unstable communication due to a lack of control.

3) NETWORK ASSISTED D2D COMMUNICATION

In this scenario, the BS supports D2D communication by controlling the signal and discovering/establishing the connection. Then, D2D users communicate in a self-organizing way, which reduces signal overhead. This configuration has merits described in the first two approaches.

D. CLASSIFICATION OF D2D BASED CELLULAR NETWORKS

D2D based communication systems can be categorized based on the frequency bands used in In-band D2D communication and Out-band D2D communication [48], [49].

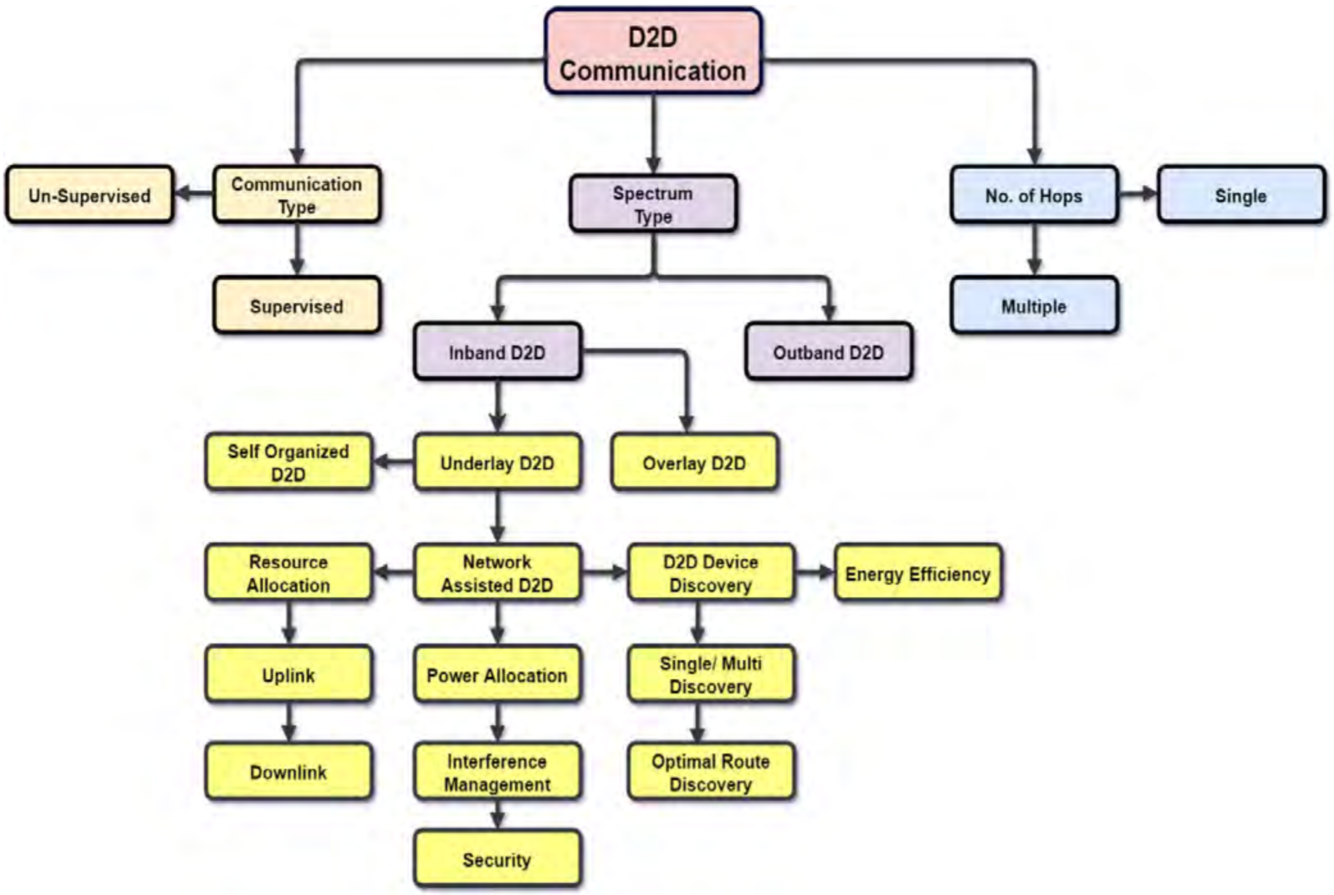

FIGURE 6. Hierarchy of Research Flow in D2D Communication.

1) INBAND COMMUNICATION

D2D communication uses a cellular network licensed spectrum. Based on spectrum sharing methods, inband D2D communication is divided into overlay and underlay mode. In the overlay inband, D2D and cellular users are assigned orthogonal resources (e.g., time/frequency). Hence, there is no interference between D2D and cellular users. However, it is insufficient in terms of spectrum efficiency (SE). In underlay inband, D2D and cellular users share time/frequency resources. Therefore, resulting in co-channel interference and efficient interference management techniques are required. Also, this method increases SE [49].

2) OUTBAND COMMUNICATION

D2D communication exploits the unlicensed ISM band also called industrial, scientific, and medical. Out-band communication eliminates interference between the users due to using a separate band instead of reusing therefore, it requires an extra radio interface. This type of communication adapts to other wireless technologies transmitting in the unlicensed band like Bluetooth and Wi-Fi. Outband communication is further divided into two types autonomous and controlled D2D based communication [44], [49].

E. APPLICATION SCENARIOS FOR D2D COMMUNICATION

There are certain scenarios that require the exchange of data between close nodes (e.g., cars, UEs, and sensors, among others). 3GPP defines three main instances for D2D, like public safety, network offloading, and commercial/social services. Additional scenarios have also been presented in the literature below:

1) PUBLIC SAFETY

The 3GPP standard proposed D2D communication for supporting emergency services and for meeting public service requirements [43]. LTE serves as an attractive solution for safety organizations (e.g., police, fire, and rescue services) that are required to intervene in case the system collapse. Failure may be the result of natural disasters (e.g., earthquakes, tornados, and hurricanes). It may be due to high congestion in extreme traffic load for crowded events (e.g., World Cup, Olympics). Safety organizations can rely on D2D technology to communicate information for short link communication between first responders.

2) COMMERCIAL AND SOCIAL SERVICES

D2D communication can support social networking in preference of fixed wireless infrastructure for communicating community information. Not only it can reduce resource usage

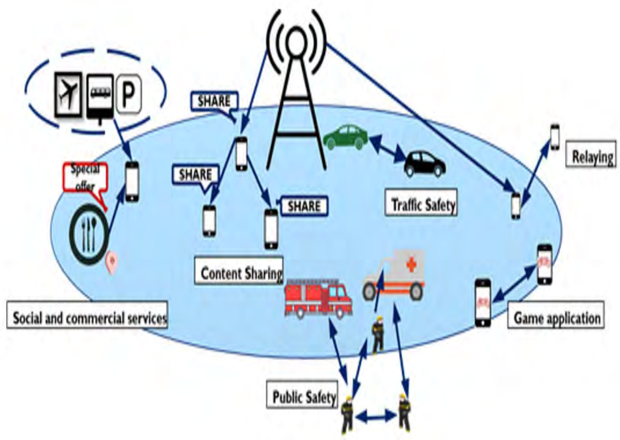

FIGURE 7. Examples of D2D Application Scenarios.

FIGURE 8. Research work in D2D Resource Optimization.

and alleviate network load, but also used for a) local promotions or advertisement from stores and restaurants located within close proximity to users [44], b) for broadcast data around community transportation facilities (e.g., schedules of trains at the station or flights information at the airport). Mobile multi-player gaming can also leverage D2D communication for social purposes. Direct link communication could offer advantages for game applications in terms of high rate, battery consumption, and low latency.

3) CELLULAR OFFLOADING

D2D communication can also be a key component for offloading network traffic. Cellular communication, when switched to D2D mode, can improve the spectrum utility because of increased overall system data rates, throughput, and proximity gain [50].

4) VEHICULAR NETWORKS

Vehicular networks are designed for vehicle-to-vehicle (V2V) communication, which is basically another application of D2D communication where nodes are vehicles. D2D communication can be used to meet strict delay and reliability requirements for Intelligent Transportation Systems (ITS). They can be implemented into collision avoidance systems by communicating road conditions (e.g., accident and road work locations) from vehicle to vehicle [51], [52].

5) CONTENT MULTI-CASTING

Content multi-casting via D2D communication works in such a way that a user with high channel quality is responsible for retransmitting received data from BS to users with weak channel quality. Data re-transmission is accomplished through D2D links [53].

F. RESOURCE MANAGEMENT (RM) IN D2D

The research work for resource management in D2D [9], [54]–[56] can be broadly categorized into different areas as shown in Fig.8. Like, [56] proposed a technique for joint D2D mode selection and proportional scheduling which confirmed the minimum interference and the required QoS demands were fulfilled. Also, the work in [57], [58] developed a joint resource scheduling and power management scheme for underlay case that guaranteed to optimize the network throughput and fairness among the users. The research work on power/energy-efficient mechanisms for D2D based LTE-A cellular networks were explored in [59] for underlay communication.

Most existing work related to spectrum reuse either in uplink [60]–[63] or downlink [64]–[70] has investigated D2D under traditional cellular networks. Downlink reuse scheme is more complicated than uplink due to high interference generated by the BSs to D2D users. In downlink reuse, the interference caused to D2D users depends exclusively on transmit power of BSs and their distance. Thus, designing efficient resource allocation schemes that can mitigate interference among cellular and D2D users is required to enhance the network performance. The resource allocation schemes include the joint mode selection, optimum power control, and channel assignment schemes for evaluating the performance of D2D under HetNets. Table. 2 summarizes the research work as mode selection (MS), power allocation (PA), resource allocation (RA), and joint PA and RA optimization.

1) RM IN D2D USING CONVENTIONAL METHODS

Extensive research work has been done on designing and developing algorithms for resource allocation in D2D based cellular networks. Researchers have utilized several approaches (e.g., optimization theory, game theory, and graph theory) to optimize various aspects of network performance (e.g., spectral efficiency, energy efficiency, and latency) in the presence of D2D communication. Existing literature can be divided into centralized and distributed approaches. For centralized methods, [85]–[88], the base station controls all the tasks of resource allocation, interference, and channel monitoring information within the cell. But with the increasing number of devices, the base stations are suffering from computational overhead. To deal with this issue many distributed resource allocation algorithms [89]–[91] have been

TABLE 2. Resource Management in D2D underlay Cellular Networks.

Ref.	D2D Range	No. of D2D/RB	MS	RA	PA	Solution Domain	Remarks
[60]	10-100m	One pair	No	Yes	Yes	Iterative Algorithm	Maximize EA and RA of D2D
[64]	20m	One pair	No	Yes	Yes	Matching Algorithms	Maximize D2D Throughput
[65]	20 m	One pair	Yes	Yes	Yes	Game Theory	Maximize System and D2D Throughput
[66]	25m	One pair	No	Yes	No	Heuristic Algorithm	Minimize Downlink Transmission Power
[67]	20m	One pair	No	Yes	No	Optimization	Maximize Overall and D2D rate
[68]	5m	Multiple pairs	No	Yes	No	Game Theory	Maximize Overall System Data-rate
[69]	10-20m	One pair	No	Yes	Yes	Auction Theory	Maximize System Data-rate
[70]	25m	Multiple pairs	No	Yes	No	Iterative Algorithm	Maximize Overall Network Rate
[71]	20m	One pair	No	Yes	Yes	Han-Kobayashi Algorithm	Maximize the Sum-rate
[72]	20m	One pair	No	Yes	Yes	Stable matching algorithm	Maximize EA and PA
[73]	20-50m	Multiple pairs	Yes	Yes	No	Iterative Optimization	Maximize D2D Sum-rate
[74]	20m	Multiple pairs	No	Yes	Yes	Graph Interference Model	Maximize Overall Throughput
[75]	20m	Multiple pairs	No	Yes	Yes	Robust Optimization Model	Maximize D2D users Sum-rate
[76]	50m	One pair	No	Yes	Yes	Convex Optimization	Maximize Energy Efficiency of D2D
[77]	15m	One pair	No	Yes	No	Analytic Solution	Maximize System Capacity
[78]	20-120m	Multiple pairs	No	Yes	Yes	Dinkelbach Approach	Optimize RA and PA of D2D
[79]	20m	One pair	No	Yes	Yes	Outer-approx Algorithm	Maximize System Energy Efficiency
[80]	25m	One pair	Yes	Yes	Yes	Non-Cooperative Game theory	Optimize Energy Efficiency of D2D
[81]	20-140m	One pair	No	Yes	No	Vertex search	Maximize Overall Throughput
[82]	20m	One pair	No	Yes	No	Greedy Heuristic	Maximize Network Throughput
[83]	15m	One pair	No	Yes	No	Matching-Hungarian Algorithm	Maximize System Throughput
[84]	30m	Multiple pairs	No	Yes	Yes	Non- Cooperative Game	Minimize System Interference

proposed in which the cellular and D2D users independently and opportunistically utilize the resources without involving base station in global information calculation. These schemes have the advantage in big network designs where interference mitigation is the concern.

The authors in [58], [92], investigated the method for improving the coverage area and maximizing throughput. [93] presented the work on energy efficiency optimization considering interference. The research in [42], [94] analyzed the initial step in D2D communication i.e, peer to peer discovery and device relaying for improving spectrum efficiency. For efficient resource optimization, the technique in [95], [96] proposed the multi-hop scenario. In [97], the authors designed the method for analyzing the performance based on D2D transmission time for improving throughput. The work proposed in [98] introduced a scheme for energy-efficient resource management in machine-to-machine (M2M) communication systems to deal with the limited spectrum and battery issues. They designed the matching algorithm-based technique to jointly optimize the device discovery, channel, power, and time slot allocation. It will maximize the energy efficiency of the overall system.

2) RM IN D2D USING MACHINE LEARNING

The conventional resource optimization schemes are not able to handle the increasing number of users with their variable channel state information (CSI). The resource management problems are mostly based on combinatorial models having nonlinear constraints for optimization which are difficult to solve. To meet up with the huge gap between the available communications technologies and future applications demands, smart and intelligent optimization schemes/algorithms must be introduced. Machine learning (ML), deep learning (DL), and reinforcement learning (RL) are the major areas of investigation in current research work that deals with the study of computational learning and pattern recognition in artificial intelligence to make decisions on complex scenarios and algorithms. This will help the cellular networks to maintain good QoS in terms of resource allocation (spectrum, power) and interference management. Further, the literature proposed in [99] provides an in-depth understanding of high-quality schemes using intelligent machine learning algorithms in communication systems [100]–[103]. Specifically, [103] proposed an intelligent resource management scheme for service provider selection and efficient power allocation in a wireless communication system. The scheme is based on the degree of mobile customers' satisfaction with QoS, considering the pricing policy and reputation of the service provider. For efficient resource management in D2D, ML plays an important role.

Works in literature focused on these solutions like in [104], the researchers introduced the method for providing ultra-reliable and low-latency services which are in high demand for future networks. The scheme is based on deep RL methods for channel and power allocation in D2D based system. A lot of work has been done in the recent past to solve the resource management problems in D2D using intelligent decision making and RL methods [105]–[108]. The work in [106] used the Q learning to maximize the system throughput, [107] used distributed method for spectrum allocation considering interference to maximize the network throughput, [108] proposed the intelligent resource allocation in D2D based vehicular networks using RL technique called as transfer actor-critic (AC). Currently, the concept of deep learning has been investigated for resource allocation scenarios [109]–[112]. The above-mentioned works in RL used the Markov decision process (MDP), which is useful when various D2D pairs or agents are renewing their policies at distinct times. But, when more than one D2D pairs or agents are revising their policies at the same time, then it will be a multi-agent problem. Recent works on multi-agent RL for resource optimization are discussed in [113]–[117]. The work done in [104], [117] is the most recent work in this regard for efficient resource allocation in D2D based systems using the latest machine learning algorithms to achieve desirable results.

VII. NETWORK SLICING TECHNOLOGY

NS is a novel technology that permits innovative models for corporate sector and fulfills the increasing demands of future cellular networks such as:

- Increased network size.
- Increased traffic volume.
- Constantly changing networks.
- Increased network complexity.

This will enable the network operators to slice the single conventional network customized for specific services into multiple logical networks [13].

The goal is to modify the existing networks according to the applications demand and migrating from "a single size fits all" to the logical solution to create the slices with resources, isolation, and applications [118]. The NS can be done in numerous domains like radio access network, transport network or core network using cloud computing infrastructure or any other network functions and resources.

A. 5G NS SOLUTIONS

The network slices provide an innovation sandbox that gives a level of isolation allowing mobile network operators the ability to build and deploy solutions without impacting all the network functions (NF) [7]. With this level of 5G automation and network slicing, service providers are expecting faster delivery of customized service level agreement (SLA) to increase the revenues and enabling new user experiences like:

- Slice life-cycle automation through simplified operations and reducing costs.
- Reduce time to market for delivering new 5G network services.
- Efficient and optimized use of valuable network resources with better insights and planning.
- The use of intelligent automation to gain an advantage in evolving and highly competitive landscape.
- To quickly meet customer's demands and ensuring their satisfaction.
- Increasing revenue with a reliable and scalable 5G network.

B. 5G NETWORK VIRTUALIZATION (NV)

5G Network virtualization is an emerging method that utilizes software-based programming to create, execute, install, and control network elements and services [119]. NV intends to provide low cost and rapid response solution to 5G services with end-to-end supervision for improving customer's Quality of Experience (QoE) [120]. Its important realization is in applications like 5G end to end program integration and Network slice as a service [121]. 5G NV concepts were proposed and implemented in previous works as software defined networks (SDN) and network function virtualization (NFV). NV allows the physical network infrastructure to decouple its applications and services. Network hyper-visor is the main component that achieves NV, examine virtual networks, and assign virtual resources to them [122].

C. 5G NS PHASES AND LAYERS

5G-based network slice comprises of different network functions for a particular business model or used case. The network slicing phases include preparation, instantiation, configuration, activation, runtime, and the decommissioning phase [119], [123]. Slicing is a new operating model accelerating the need for automation through cloud computing. NS has three types of layers [124] as in Fig.9:

1) SERVICE INSTANCE LAYER

This layer supports the customer and business services with every single service representing a service instance for use.

2) SLICE INSTANCE LAYER

This layer represents the instances that are available at the network. Each network slice instance delivers the system characteristics as desired by the upper service instance.

TABLE 3. Resource Management in Network slicing based 5G cellular Networks.

Ref.	Network	System Model	Objective	Remarks
[125]	Access	Business Model	Maximize data-rate	Provide more gains and fairness with dynamic slicing than static network slicing
[126]	Core + Access	Generalized Model	Minimize packet delay	Efficient resource allocation by virtual networks for various network topologies
[127]	Access	Business Model	Maximize revenue	Provide best pricing decisions on handling network slice request
[128]	Core	Economic Model	Minimize cost	Optimize virtual networks on various cloud networks for partnership
[129]	Access	Generalized Model	Maximize throughput	Efficient channel allocation with users association and power allocation method
[130]	Core	Schwarz-Christoffel	Minimize packet delay	Optimize the arrival rate of session requests
[131]	Access	Predictive Model	Maximize resource utilization	Predicts the trend and seasonal variation in future data traffic
[132]	Access	Predictive Model	Maximize energy efficiency	Efficient isolation in network slices with customized facilities in every slice
[133]	Core	Recovery Model	Maximize capacity	effects of random traffic variation with limited resources and robust
[134]	Core	Robust Model	Optimize bandwidth usage	Re-design and reroute the newly created VNFs due to failure
[135]	Core + Access	Generalized Model	Optimize bandwidth and time dependent pricing	To solve asymmetric information and price discrimination for software defined networks

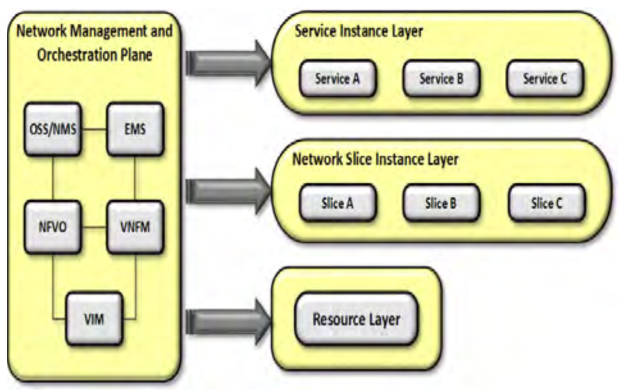

FIGURE 9. Slice Layers Function.

3) RESOURCE INSTANCE LAYER

This layer offers entire system resources including both physical or virtual and different network functions required to generate a network slice instance.

D. RESOURCE MANAGEMENT IN 5G NS

Table. 3 provides the overview of research work done using the NS concept in 5G cellular networks. It summarizes the comparison of system models considered in [125]–[135], the main objective of work and network models used.

E. BUSINESS PERSPECTIVE OF 5G NS

5G NS is an emerging technique that provides a customized service experience to subscribers, using the concepts of virtualization and cloud computing. Today the market is driving the need for network slicing due to increased network size, traffic volumes, varying deployment models through hybrid cloud infrastructure [124]. All of them contribute to increased network complexity. Service providers are looking to build network slices based on the resources and components that are available in existing networks.

Depending on the vertical 5G used cases as discussed in Section V-A such as mMTC or eMBB, the network resources attached to those services are assigned that slice [124]. Network slicing uses the same physical infrastructure and creates logical partitions of the network based on the different SLA of the industries or vectors. Based on the 5G used cases and an increase in the no. of devices and services requires the need for slice automation. 5G automation is a key driver for network slicing which enables mobile network operators to build customized solutions and offerings.

F. RESEARCH WORK IN D2D WITH NS

The research work on using D2D with network slicing concept in 5G cellular networks has not been explicitly explored to date. Previously, work has been done using SDN and virtualized networks which is still in its infancy [143]. For virtualized networks, the SDN controller or slice controller is responsible to direct the D2D connection for a successful session. This is a more effective method to coordinate D2D pairing or to use the existing cellular mode. The virtual SDN/slice controller directly sends commands to cellular devices with equivalent functions, despite using the control

TABLE 4. Resource Management in Virtualized D2D based Cellular Networks.

Ref.	Network Model	System Model	Algorithm	Objective	Remarks
[136]	Traditional	Underlay/ Uplink	Heuristic	To optimize resource slicing of D2D	Increased system throughput with minimum interference
[137]	Virtualized	Underlay/ Uplink	Stochastic	To formulate the resource sharing problem for D2D in imperfect network state	Maximize the sum rate utility in imperfect channel conditions
[138]	Traditional	Overlay	Stochastic	To allocate spectrum to D2D users in a multi-operator scenario	Efficient spectrum allocation scheme for considerable performance improvement
[139]	Virtualized	Underlay/ Uplink	Heuristic	To design a resource sharing scheme for D2D users in different virtual operators	Maximize Sum-Rate to achieve good performance
[140]	Virtualized	Underlay/ Downlink	Heuristic	To assign the virtual resources in D2D based LTE system considering interference	Maximize the overall system Sum rate
[141]	Virtualized	Underlay/ Downlink	Distributed	To design the information centric and virtualized D2D among different operators	Optimize the total system utility by efficient resource allocation
[142]	Virtualized	Underlay/ Uplink	Heuristic	To optimize the operator's profit by efficient resource allocation	Optimize the D2D and cellular users sum rate with maximizing the total profit

plane procedures. The virtualized D2D cellular networks must guarantee higher system performance and massive connectivity for devices to minimize the delay and hardware expenses as compared to current wireless networks. The research work in [144] proposed maximization of throughput for both D2D and cellular users in a virtualized LTE system. [140] verified that using virtualization for resource optimization can improve the system performance and throughput. Further, [139] proved better capacity and optimizing the sum rate when D2D users are related to multiple operators. Reference [143] studies the effect of resource aggregation in a virtualized common pool for D2D receivers and transmitters so that efficient resources can be allocated for available for D2D systems. Table. 4 presents the comparison of work done in D2D based cellular networks using virtualized networks. No detailed work is done in D2D with network slicing. This work is still in its initial phase.

G. 5G NS FEATURES

Main features of 5G Network Slicing and virtualization are [145], [146]:

1) NETWORK FUNCTIONS AUTOMATION

This includes automation of dynamic network slice life-cycle (e.g., creating, adding, or deleting), resource optimization of networks, and dynamic interchange among data and administration planes [146].

2) IMPROVED SCALABILITY, ISOLATION AND RELIABILITY

These are the key aspects of network slicing in 5G that are capable of instant damage discovery mechanisms for every tenant and guarantees their security and dynamic performance needs [145]

3) PROGRAMMABILITY

This feature automates the availability of customer services and network management challenges particularly in communication applications [147]. The Programming of slices enables third parties to monitor and manage the assigned resources (like network and cloud resources). This helps in demand-oriented customized services and resource flexibility for virtual networks [148].

4) HIERARCHICAL LEVEL ABSTRACTION

Network virtualization defines an abstraction layer by logically and physically partitioning different resources and network functions [149]. This enables on-demand service provisioning from a network slice, for instance, service providers and operators can facilitate manufacturing organizations to exploit the network as a service [150].

5) CUSTOMIZED SLICES

This feature is recognized at every level in the virtualized network with SDN in control and data plane. By using the concepts of Artificial Intelligence, the network virtualization on the data plane will deliver personalized services with value-added packages [148].

6) RESOURCE FLEXIBILITY

This will enable the assigned resources to scale up and down effectively according to the system requirements. The resource elasticity guarantees the requested service level agreements of customers irrespective of their location [151].

VIII. MOBILE EDGE COMPUTING (MEC)

Mobile Edge Computing (MEC) is the term derived from previous cloud/central computing concept. In MEC all the storage, computation tasks are performed at edge of the network using small edge servers. This eliminates the need for transmitting information to the core network for processing. There are two major advantages of using the concept of MEC in existing cellular networks.

- Offloading: Energy saving for devices by offloading the exhaustive computing assignments.
- Congestion: The processing is now at the neighboring base station instead of the central cloud; therefore, the core network congestion and end-to-end delays are reduced significantly.

Recently, a lot of research has been done for MEC based networks to improve the system performance in improving energy usage [152]–[154] and delay [155]–[157]. However, the inadequate computing resources at the base station are not always sufficient to meet the requirements of devices.

A. MEC WITH D2D

D2D is known for its benefit in offloading the neighboring device burden and reducing the central network congestion, so this motivates the combination of D2D with MEC providing advantages of resource reuse gain, hop gain, and proximity gain. These benefits are only possible by wisely designing the network and addressing the main issues that will arise due to the addition of D2D. Numerous studies in the literature have examined the effect of adding D2D offloading concept with MEC [158]–[161]. The work in [158], [159] investigated how the system performance and energy efficiency can be improved with D2D. Reference [160] proposed an innovative model of improving energy efficiency. The system will be offloading the tasks using D2D mobile devices for sharing the computation and communication resources. Similarly, for optimized system burden offloading, authors in [161] introduced a strategy for D2D using the non-causal processor information. The aforementioned work with joint D2D and MEC focused on improving the energy efficiency and reducing the end user's latency, but [162] proposed the scheme for computational capacity maximization. The work done in [104] is the very latest work for D2D using the concepts of MEC and machine learning. It is based on providing ultra-reliable and low latency applications in upcoming networks. By using a double deep Q-learning approach channel and power allocation problem can be solved efficiently in D2D based underlay cellular networks considering interference. The edge devices (D2D TXs) establishes the power assignment for improving spectral efficiency with desirable cellular users QoS.

IX. PROPOSED 5G NETWORK WITH D2D, NS AND MEC

The network design of the proposed model can be shown in Fig. 10. It has various network sections [163]:

- Core network (CN)
- Transport network (TN)
- Mobile edge computing network (MEC)

1) CORE NETWORKS (CN)

Just like the previous SDN/NFV techniques, the NS based CNs are anticipated to be implemented as VNFs that can run over virtual machines with the edge/fog based networks [164]. Such virtualized functions can be installed at a variety of locations in a network considering explicit application demands. Core network will slice the single common physical infrastructure into multiple logical slices depending on the application requirements. Like as in Fig. 10 Smartphones, Video control, smart city, smart wearable, e-health, smart industry, 3D Video are the services. Depending on these services the network management and orchestration plane will create the slices like eMBB slice, mMTC slice and URLLc slice.

The network slice controller is responsible for instantiating and managing the slice based on attributes characterized by the network slice type. It will begin the instantiating appeal to configure, create, and initiate the slice. After activation, the slice is controlled and monitored to fulfill the desired Quality of Service (QoS) or Service Level Agreement (SLA) requirements. The orchestrator and optimizer will monitor the network slice in real-time to make modifications and to meet the SLA [123]. The slice which is not required is deactivated and the allocated resources will be released.

2) TRANSPORT NETWORK (TN)

In future transport networks must be executed to accommodate numerous applications and customized services. The layout of slicing based transport networks can be implemented with suitable interfaces using NS infrastructures. The control panel will be responsible for resource discovery and optimization management. In a virtualized TNs, the factors like mobility management and load balancing aspects can be effectively coordinated with the interaction of RAN [165].

3) MOBILE EDGE COMPUTING (MEC) NETWORK

This is basically the physical layer which intends to shift network functions, resources, and content close at the consumer end. This is achieved by expanding traditional data processing units towards the network edge. The programming-based platforms that monitor the information-centric networking (ICN), will execute the NS process in edge networks [123], [166]. Edge computing is an emerging technique for intelligent machine learning and context-aware applications in edge devices of 5G network [7]. The aim is to deliver the increased throughput and quality of experience (QoE) for next-generation mobile networks including 5G and beyond [167]. With content-aware caching solutions and social relationships aware networks in edge computing servers, the virtualization of mobile edge networks ensures to minimize the load at the core networks. This will improve the capacity in case of high volume data processing, enabling real-time applications and optimized usage of resources [168].

The substrate resources of infrastructure provider are sliced into multiple virtual network operators called MVNO. In this way, capital expenditures (CAPEX) and operation expenditures (OPEX) of the network will reduce significantly [169].

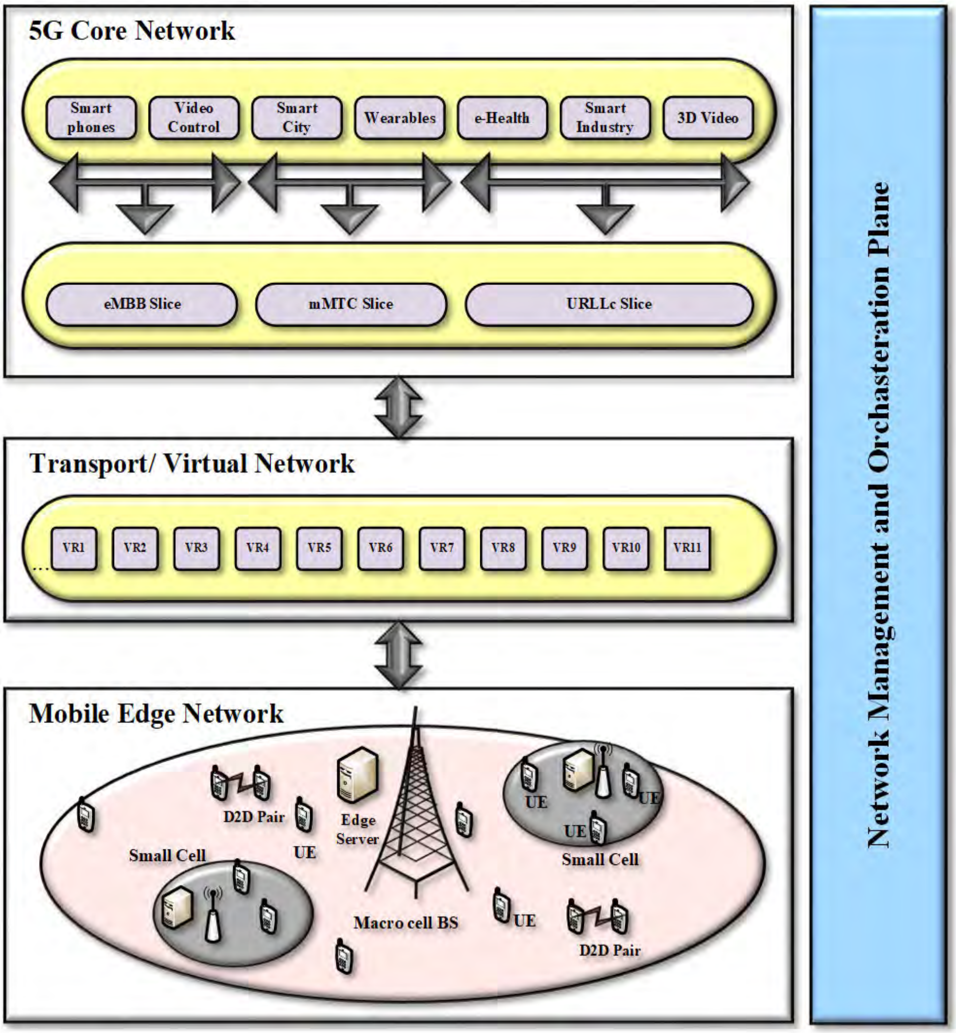

FIGURE 10. 5G Network Slicing Architecture.

Each MVNO operating above virtual networks can deliver user's services on demand, which enables the attraction of many new subscribers. InP's will substantially gain more profits by renting individual virtual slices to different MVNOs [170].

The network utilization is increased by maximizing network resource sharing. Mostly by reusing different slices and by allocating new resources to different slices. This provides the mobile network operator with increased agility and faster time to revenue by providing a multi-tenant network slicing solution [121]. The business benefits of network slicing allow mobile network operators, the ability to automate the creation of network slices in a matter of minutes by using the same physical infrastructure.

By adding the D2D and edge routers at the radio access network shown in Fig. 10, the computation tasks can be done more efficiently, and backhaul load can be reduced considerably. 5G network slicing enables mobile network operators to become flexible and dynamically adjust network slices based on utilization capacity and customer SLA requirements. It is believed that by considering all the constraints properly and introducing innovative optimization techniques, the proposed network architecture will meet the goals of future generations.

X. DISCUSSION ON INTEGRATING D2D, NS AND MEC

The next generations of mobile communications, 5G and beyond are believed to have four main characteristics:

- Firstly, they are ultra-dense networks with the enormous growth in the number of mobile devices and data requirements.
- Secondly, the QoS needs are robust to sustain extremely high-data-rate, ultra-low-latency, reliability, and throughput.
- Thirdly, the networks should support heterogeneous technologies for compatibility of various user's types (like smartphones, tablets), network types (like cloud and edge computing, IEEE 802.11, Internet of things), and QoS types (like different values of speed, delay, and throughput for specific applications), and

- Fourthly, the massive multiple-input multiple-output (MIMO) concept at the base stations to minimize the interference and permit the nodes to broadcast simultaneously at the nearby locations.

Next generations data rate demand in terms of delay can be categorized as:

- Intense real-time: is for some strict latency requirement applications (like online gaming, health monitoring, and air traffic control).
- Mild real-time: is for services that can endure some delay values (like control of traffic signals, multimedia data transmission, and reception).
- Non-real-time: is for applications that can tolerate the delays and are not time-dependent (like email, forum communication).

MEC is known for its benefits in data with real-time applications (pre-defined latency) requirements using edge servers at nearby locations to the users. Such a decentralized network design will reduce the latency as compared to central cloud computing and will serve the demands of extremely interactive services with high computation and QoS needs. MEC have multiple mini edge servers placed at the edge network which may compute data in a single or collaborative mode to the cloud/central server placed at the core network [171], [172]. They will meet the 5G demand for ultra-low latency and will reduce the energy consumption by approx. 40% due to five times less access to the central cloud [25], [173].

MEC technology with small computing servers located at the edge of networks take advantage of previous NFV and SDN concepts, augmenting it with new storage/computing resources and creating multiple network slices based on services. MEC provide advantages of high bandwidth, less delay, offloading, location and real-time awareness about radio access networks. It will enable the improved customer's experience with good network QoS, less data transmission cost and reduced congestion. NS based MEC servers will deliver storage, computing and bandwidth capability that is shared by multiple logical slices directly connected to the base stations, owned by the infrastructure provider [174]. This will eradicate the requirement of forwarding data to the core network as most of the computation is performed at edge nodes resulting in lower latency.

Although a lot of work has been done independently in these areas the recent advances in integrating them are mostly ignored in the literature. Combining D2D with SDN and NFV was proposed in [175] which shows that throughput of the system can be improved in imperfect channel conditions. The work in in [140] proposed that using D2D in wireless virtual networks can significantly improve the system throughput. Similarly, [176] proposed the structure for software based information centric cellular network with D2D to optimize the network utility function. The optimization problem was based on resource allocation and caching parameters.

Adding D2D technology in the networks can provide the benefits of (1) Reuse gain (same resources can be used by both cellular and D2D users), (2) Proximity gain (based on the distance between D2D devices to provide increased bit rate, low power consumption, and less delay), and (3) Hop gain (D2D devices can use a single link instead of uplink and downlink). The integration of D2D with NS and MEC requires a substantial modification in both core and access networks to support the smart services in future innovative infrastructures.

Slice controller is the main entity responsible for the management and operation of the network infrastructure [177]. NS helps to provide abstraction and isolation of network resources. 1) effectively managing hardware resources, 2) introducing innovative functions and services to the marketplace, 3) easily upgrade and maintain the network, 4) minimizing CAPEX and OPEX, 6) encouraging a diverse environment. Despite these advantages, the operation and maintenance of virtual network functions (VNFs) are challenging considering the MEC platform. NS has been considered as improved technology to provide scalability and flexibility of virtual resources.

NS is an essential technology to manage the diversity of D2D based services. The advantage of heterogeneous network services is that the devices can connect to multiple network slices (for specific services) at the same time. The concept of virtualization in D2D can be extended to include different 5G use cases scenarios. An important case in this regard is mMTC in which the devices communicate with each other. Incorporating network slicing with D2D communication is believed to enhance system performance in various mMTC applications [176]. The resources in a specific slice are isolated from other slices that can provide the improved quality of service (QoS) demands and thus alleviating the interference. D2D communication improves system throughput by less bandwidth usage, minimum path loss, low power consumption, and decreased cost as compared to traditional cellular communication.

By efficiently optimizing spectrum and energy efficiency in the proposed network, it is expected that higher throughput with less transmission delay and energy savings can be achieved. This survey examines features of 5G cellular networks, Network slicing, D2D based cellular networks, and MEC individually and what are the benefits and trends achieved when all these technologies will combine in upcoming future generation networks. This will reduce computational burden and delay for real-time applications in complex future network architecture [23].

XI. OPEN CHALLENGES AND FUTURE TRENDS

The new 5G network architectures will be more complex than the existing ones, so every issue needs to be tackled very carefully for the best results.

A. CHALLENGES IN D2D COMMUNICATION

The addition of D2D communication in existing network designs introduces technical challenges. Some of them are discussed in [44], [48], [49]:

1) SYNCHRONIZATION WITH PEER DISCOVERY

Throughout the device discovery stage, UEs try to find possible candidate UEs located within a specified proximity to establish direct communication. Then, synchronization among UEs is leveraged for efficient use of the available spectrum and of the UE energy [45], [49], [178]. There are generally two approaches: direct and network-assisted device discovery. In direct device discovery, UEs periodically broadcast discovery beacon signals. Hence, UEs located nearby can identify their presence and determine whether setting up D2D communication is warranted; however, since there is no synchronization between nodes, and receiver nodes continue to listen for beacon signals all time, this results in a UE battery drain and an increase in energy consumption. Also, this approach is distributed and does not involve BS in the discovery process. Thus, illegal users might listen to data during D2D communication. Another shortcoming of this approach is unrestrained usage of the licensed band [44], [49]. In network-assisted discovery, UEs inform the BS regarding their intent to connect and then send beacon signals. BS exchanges some messages, including identity and link information between two UEs for initiating a D2D link. This approach is centralized, and UEs listen only when instructed by the BS. The result is less energy consumption; however, this method comes at the cost of larger overhead, and limitations in privacy and scalability [42], [179].

2) MODE SELECTION

Mode selection can be described as the process of switching between the D2D mode (DM) or cellular mode (CM) should be used. Further after mode selection, the device must choose that if the D2D link will reuse the cellular links resources (i.e., underlay) or will use direct link (i.e., overlay). Mode switching can be performed statically before the D2D link setup or dynamically as per time slot basis. This is an important decision because sometimes direct link quality could be worse than cellular link quality. Design issues related to model selection can be described as follows. First, at what timescale should mode selection be performed and, subsequently, what measurement control signals are required, noting that the timescale cannot be too coarse. To avoid signal overhead, measurements and required control signaling should be kept at a minimum. Second, measurements (e.g., Signal-to-Noise ratio (SNR), path loss, distance) should be used to decide the mode of the users [46], [85].

3) INTERFERENCE MANAGEMENT

The major problem in D2D based communication is the interference caused due to reuse of cellular channel resources. Efficient spectrum allocation and power management techniques can significantly mitigate interference and maximize network performance, and they typically occur simultaneously with mode selection. This issue is quite challenging; therefore, proper allocation of resources is necessary to maintain the required user's QoS. Two types of interference can occur cross-tier interference that is between cellular users and D2D pairs by reusing the same resource and co-tier interference that is among two different D2D pairs sharing a similar channel. Various interference management techniques were proposed for D2D communication under conventional cellular networks for both UL and DL spectrum reuse [85], [178]. When D2D communication coexists with heterogeneous cellular networks (i.e., HetNets), interference management techniques become more complicated, as they take into consideration the dense deployments of small cells.

The details of research work in resource (channel and power) allocation considering interference are thoroughly explained in Section VI-F. Similarly, Table 2 summarizes the work done in Underlay D2D communication where interference is the main constraint considered in problem-solving. Most of the work done in D2D is on single-cell networks but [84] proposed a detailed technique for interference mitigation in multi-cell D2D based cellular networks. They introduced a two-step method, where the first performs resource block allocation using a non-cooperative game and the second one divides the total interference problem into multiple minimization problems for efficient power allocation. Similarly, [180] provides a comprehensive understanding of resource allocation in next-generation wireless networks where the intra-cell and inter-cell interference has a great impact in evaluating the performance of the overall system. Notably, the interference mitigation problem of HetNets with D2D communication is still an open area for investigation. However, by using efficient and intelligent techniques for interference mitigation, the achievable data rate and QoS of end-users can be improved significantly.

B. CHALLENGES IN INTEGRATING D2D, NS, AND MEC

1) DYNAMIC RESOURCE ALLOCATION SCHEMES

Radio resource management is the major challenge that still needs to be improved for 5G core and radio access network domains. Available research work on 5G network slicing lacks the issues of new modulation techniques, massive MIMO, power consumption, and energy efficiency. The majority of the literature focused on finding the sub-optimal solutions by using different optimization methods. Next is to control power consumption to avoid interference in heterogeneous 5G cellular networks [11], [181].

2) LIMITATIONS OF EXISTING DEVICES

Using MEC technology for future cellular networks helps in overcoming the problems of centralized networks. But, they are faced with the challenges of device capabilities in caching the content, capacity, battery consumption, and storage. Consequently, when to offload the content and how to choose the caching node must be significant factors to consider [23]. D2D with MEC has been extensively explored over the past few years by academicians and industrialists for its benefits in offloading and emerging spectrum efficiency improvement many research issues need to be addressed to date.

3) CHANNEL CHARACTERISTICS
The most critical issue that should be investigated is the virtualization of physical channel characteristics and to enable isolation among various slices. The logical channel characteristics must be known to the devices so that they can support the device discovery, proximity aware services (ProSe), content caching, and relaying features in D2D edge computing. This is challenging in designing the cellular communication to avoid overhead and congestion losses.

4) COMPATIBILITY ISSUES
Integrating various radio access technologies (RATs) and their compatibility is challenging and extensive research work should be done. Several issues like resource utilization, interference management, power optimization congestion, and collision must be investigated in the upcoming networks. Advanced modulation techniques must be considered in designing the networks.

5) EDGE DEVICE RESOURCES
The mobile operators may install edge servers at the base stations to avoid burden at the cloud server and to achieve prompt response for customized services. Still here, the edge device's battery-saving and efficient utilization of scarce resources remain the test. New opportunities are required to work on resource scheduling techniques and virtualization without compromising the system performance and gains.

6) MOBILITY MANAGEMENT
For allocation of virtual resources, the mobility management factor of devices needs to be investigated with controlled handover to improve the spectrum utility in 5G networks [182]. The major challenge in D2D communication is its short-range requirement for a reliable link. As the distance between two devices increases, the connection will break so a solution must be required. For example, in the vehicle-to-vehicle scenario, the vehicle moves from the area of one base station to the other connected to a different edge server. The computation tasks are assigned to the new edge server through handover and the delay in this process is reduced by edge computing technology [22]. However, research in this area is very less and challenging. New optimized techniques need to be introduced for best network performance.

7) NEW FREQUENCY BANDS
Analysis must be done on the correlation between the unlicensed spectrum and licensed spectrum to efficiently utilize the current and new frequency bands. This is particularly becoming necessary with emerging spectrum sharing and spectrum sensing methods. Dynamic bandwidth slicing and sharing issues considering interference must require intelligent techniques [183], [184], therefore research must be done on novel intelligent learning algorithms like deep reinforcement learning techniques, machine learning, neural network, and long and short-term memory.

8) HARDWARE MODIFICATION
The shift to network virtualization of core and access layers are still very slow because most of the processing hardware components are dedicated and centralized. With the evolution of cloud-based networks, the components have started getting distributed and virtualized. The storage capacity is the main issue for dependence on dedicated hardware systems [185].

9) NOVEL SLICE CREATION TECHNIQUES
The authors in [186] concluded that innovative slice creation techniques based on descriptive configurations, information-oriented, and customized service requirements must be investigated across each network layer by intelligent slice orchestration. Slice controller management in dealing with resource allocation issues of all slices and dedicated slices must be explored.

10) SECURITY
Another important factor is the security that must be considered to provide the users with trust. As new services are emerging and customers every form of data is shifting to cloud networks, the serious concern is to develop efficient and intelligent techniques for privacy and secrecy [187], [188]. This will build the user's satisfaction and motivation to use new services.

11) NEW BUSINESS MODELS
An important challenge is to introduce versatile business models for operators and service providers which maximizes their utility functions and percentage of benefits achieved to shift from a centralized system [14], [189]. Good pricing and revenue based schemes must be explored for meeting the challenges of existing market. Pricing criteria for D2D acting as a relay and information centric networks is a serious concern of the service providers. Further, considering the new business opportunities and economic factors with both the single and multiple operators and infrastructure providers point of view.

C. FUTURE TRENDS
The proposed work can be extended in many ways with most important recommendations are:

1) HETEROGENEOUS INTERNET OF EVERYTHING (IoE)
In the future, the devices are intended to provide multiple smart services. The devices should have the capability to enable heterogeneous IoE services like very high-frequency communication, virtual and augmented reality services, fully automated systems for telemedicine and transportation.

2) LONG PACKETS FOR COMMUNICATION
5G is built with the short communication packets having ultra-reliable and low latency features, but in the future, like 6G various applications e.g., augmented reality and autonomous vehicles need long communication packets

having ultra-high data rate and ultra-high reliability properties. Extensive research work with efficient optimization models must be designed to meet these future requirements.

3) 3D CELLULAR NETWORKS

Several new types of use cases and service providers are anticipated like 3D cellular network service providers, haptics communication providers, new nano-IoT applications, telemedicine service providers. These service providers are specialized to provide a whole new range of services different from 5G networks.

4) DYNAMIC D2D NETWORK ARCHITECTURE

A novel and dynamic D2D network architecture with high mobility case must be designed for reliable and long-lasting connection that allows control of reliable connections. Efficient network models for D2D based heterogeneous networks scenarios are required for improving throughput and QoS requirements.

5) INNOVATIVE NETWORK SLICING ALGORITHMS

New innovative business models are required for enabling network slicing in future generations of mobile networks [14]. Adaptive schemes for network slicing life cycle management are expected to manage and control the dynamic features of future networks. The network slice creation, deletion, and update must be linked with the service time scale depending on the diverse QoS demands.

6) NETWORK SLICING FOR 3D NETWORKS

The future equipment and base stations are predicted to be drone-based like in 6G cellular networks. Network slicing-based 3D cellular networks are recommended in the future for efficient orchestration and management of network function resources.

7) INTELLIGENT MACHINE LEARNING MODELS

For future networks, machine learning is believed to be an essential part of managing smart applications. By using these concepts intelligent network slicing and edge computing models can be designed. Machine learning requires initial training data sets and detailed simulations for tuning the machine learning parameters. Deep Q learning and Reinforcement learning concepts are recommended for future generations of cellular networks due to the rapid increase in intelligent smart applications. New meta-learning based techniques should be introduced for network slicing and edge computing to minimize the delay in transmission.

XII. CONCLUSION

The proposed work gives a comprehensive understanding about the recent hot topics in 5G technology i.e., D2D, NS, and MEC. Many schemes were previously proposed by the researchers but were incomplete in one way or the other. They were based on a trade-off between different parameters. D2D, MEC, and NS are continuously developing independently. The conventional cellular network design is not capable to support emerging applications demand. This study addresses the idea of integrating D2D, MEC, and NS to achieve their individual gains. Such a network design will open a new era of revenues for mobile operators while reducing the complexity and cost of the system. This will fill the gap with multiple domain-based systems to enable the availability of resources according to customized slice requirements by efficient management of slice controller. The benefit of MEC is also promising to add in current networks to deal with complex situations. NS has given rise to a plethora of emerging new vertical industries and services each requiring its specific network requirements. This has led to the increased complexity and the need to consolidate solutions into one vendor a multi-tenant network slicing solution enabling to unlock new revenue streams and services. By using D2D, the spectrum can be used more efficiently with less delay. Other improvements include a reduction in time to market and an increase in network efficiency as well as minimizing network complexity, with reduced latency, increased throughput, and increased connection density.

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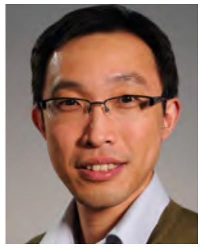

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