5G Internet of Things: A Survey

Shancang Li[a], Li Da Xu[b,c,d], Shanshan Zhao[e]

[a] *University of the West of England, UK (email: shancang.li@uwe.ac.uk)*
[b] *Institute of Computing Technology, Chinese Academy of Sciences, Beijing 100190, China*
[c] *Shanghai Jiao Tong University, Shanghai 200052, China*
[d] *University of Science and Technology of China, Hefei 230026, China; Old Dominion University, Norfolk, VA 23529, USA (e-mail: lxu@odu.edu).*
[e] *Engineering Modelling and Simulation (EMS) research group, University of the West of England, UK (e-mail: shanshan.zhao@uwe.ac.uk)*

Abstract

The existing 4G networks have been widely used in the Internet of Things (IoT) and is continuously evolving to match the needs of the future Internet of Things (IoT) applications. The 5G networks are expected to massive expand today's IoT that can boost cellular operationgs, IoT security, and network challenges and driving the Internet future to the edge. The existing IoT solutions are facing a number of challenges such as large number of conneciton of nodes, security, and new standards. This paper reviews the current research state-of-the-art of 5G IoT, key enabling technologies, and main research trends and challenges in 5G IoT[1].

Keywords: Internet of things (IoT), 5G, wireless communication,

1. Introduction

The evolving of fifth generation (5G) networks is becoming more readily avaialbe as a major driver of the growth of IoT applications [2]. According to the International Data Corporation (IDC) report, the global 5G services will drive 70% of companies to spend $1.2 billion on the connectivity management solutions [2]. New applications and business models in the future IoT require new performance criteria sucha as massive connectivity, security,

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trustworthy, coverage of wireless communication, ultra-low latency, throughput, ultra-reliable, et al. for huge number of IoT devices [4]. To meet these requirements, the evolving Long Term Evolution (LTE) and 5G technologies are expected to provide new connectivity interfaces for the future IoT applications. The development of next generation of "5G" is at its early stage, which aims at new radio access technology (RAT), antenna improvements, use of higher frequencies, and re-architecting of the networks [6]. However, main progresses have been made and the evolution of LTE needs to be complemented with a radical change within the next few years in the fundamentals of wireless networks - a generational shift in technology and architectures and business process.

According to the Gartner, up to 8.4 billion IoT devices will be in connected through machine-to-machine (M2M) by 2017 and this number will reach 20.4 billion by 2020 [1]. The 5G enabled IoT (5G-IoT) will connect massive number of IoT devices and make contributions to meet market demand for wireless services to stimulate new economic and social development [59]. The new requirements of applicaitons in the future IoT and the evolving of 5G wireless technology are two significant trends are driving the 5G enabled IoT [59].

In the past few years, many research efforts have beed made on both 5G technologies and the future IoT. A number of key enabling technicals in 5G are developed to offer new infrastructure and design with inherent capabilities requried by the future IoT [3]. The authors reviewed most recent reserch results from two major academic databases (IEEE Xplore and ScienceDirect)to understand the current status and future research on both 5G and IoT. We noticed that in the past four years from 2014 to 1st Jan 2018, 389 IoT and 5G related papers have been published by IEEE Xplore and 588 papers have been published by ScienceDirect. Figure 1 indicates the number of articles stored in IEEE Xplore and ScienceDirect from 2014 to 2018.

The rest of this paper is organized as follows: Section 2 presents the background and current research of 5G and IoT. Section 3 provides an indepth review of key enabling technologies that make 5G-IoT possible. Section 4 discusses research challenges and future trends. Section 5 concludes the paper.

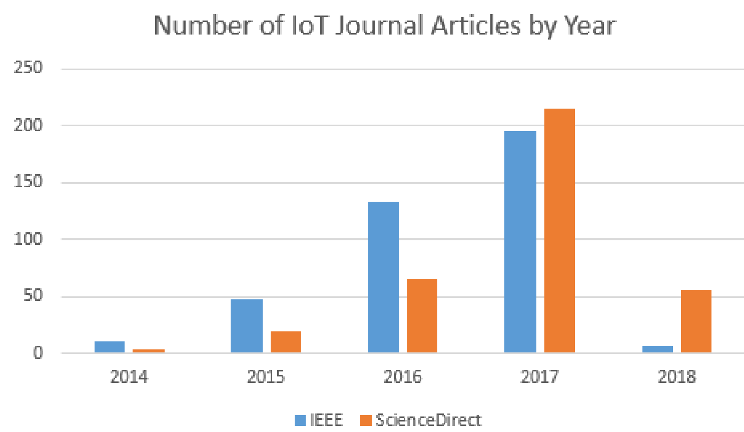

Figure 1: Number of 5G-IoT Journal Articles by year in IEEE and ScienceDirect

2. Background and Current Research of both 5G and IoT

In the heterogeneous IoT, a number of wireless technologies, such as 2G/3G/4G, WiFi, Bluetooth, etc., have been used in IoT applications, in which billion of devices will be connected by wireless communication technologies [20]. The 2G networks (currently covers 90% of the world's population) are designed for voice, 3G (currently covers 65% of the world's population) for voice and data, and the 4G (since 2012) for broadband internet experiences. The 3G and 4G are widely used for IoT but not fully optimized for IoT applications [20]. The 4G has significantly enhanced the capabilities of cellular networks that can provide IoT device usable Internet access. Since 2012, the 'long term evolution' (LTE) to 4G connectivity, became the fastest and most consistent variety of 4G compared to competing technologies such as BLE [21], WiMaxb[22], ZigBee [23], SigFox [25], LoRa [26], etc. As the next-generation networks, the 5G networks and standard are expected to solve challenges that facing by 4G networks, such as more complicated communication, device computational capabilities, and intelligences, etc., to match the needs in smart environments, industry 4.0, etc. [8].

Figure 2 shows the evolution of the cellular networks from 3G to the next 5G enabled IoT [4]. The development of 5G will be based on the foundation created by 4G LTE, which will provide user voice, data, Internet. The 5G will significantly increase the capacity and speed to provide relabile and speedy connectivity to the future IoT. The current 4G LTE can provide a transmission speed as 1Gbps, however the 4G signal could be easily disrupted by inferences, such as WiFi signals, buildings, microwaves, etc [20]. The 5G networks can provide users with faster speed than 4G up to 10 Gbps, meanwhile the 5G can provides reliable connection up to thousands device at the same time [1, 20, 21].

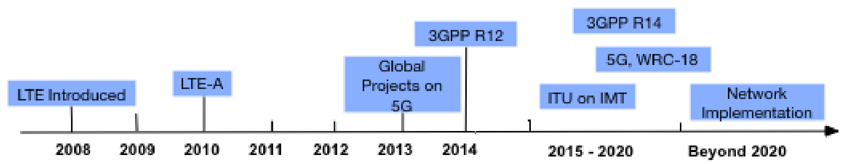

Figure 2: Timeline towards 5G [4]

Figure 3 shows that in IoT massive machine type communication (MTC) applicaitons in smart cities, healthcare system, etc. requires massive connection networks, which create a huge heterogeneous of IoT and create many implementaiton challenges. In the past two decades, a number of M2M communicaiton technologies have been implemented, including short-range MTC such as Low energy bluetooth (BLE v4.0) [21], ZigBee [22], WiFi, etc. and long-range communicaiton, such as Low-Power wide-area (LPWA) [23], Ingenu random phase multiple access (RPMA) [24], SigFox [25], LoRa [26], etc. To ensure that M2M applications, the three generation partnership project (3GPP) proposed Enhanced Machine-Type Communication (eMTC), Extended Coverage-Global System for Mobile Communications for the IoT (EC GSM-IoT) and Narrowband-IoT (NB-IoT) as cellular-based LPWA technologies for the IoT [20]. Existing communication technologies are diverse and it is challenge for the fifth generation (5G) mobile network to meet the requirements of applicaitons in IoT [20].

2.1. Wireless networks in 5G

The wireless technologies has singificantyly enhanced the deployment of IoT, a number open standard for IoT have been released, such as the Vodafon's Cellular IoT [60] and the NB-IoT based on 3GPP [61]. The 5G will be able to provide connection massive IoT, where billions of smart devices can be connected into the Internet. The 5G networks will provide a flexible and faster networks, which can be implemented through the wireless software-define networking (WSDN) paradigm [11]. A number of WSDN solutions for 5G have been proposed, including SoftAir [12], CloudRAN [13], CONTENT [14], et al.

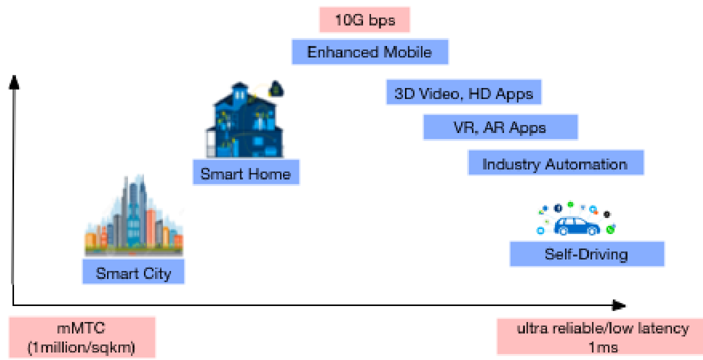

Figure 3: MTC in 5G-IoT

The IoT has the potential to provide users with smart services, while raising security and privacy questions and offering new challenges to standardization and governance bodies [9]. The 5G technology can significantly expand IoT beyond what is possible with existing technologies. The 5G wireless network will enable IoT devices to interact with smart environment to a new level through intelligent sensors connected. The 5G wireless network can also significantly enlarge the scope and scale of coverage of IoT by providing the fastest communication and capacity [14].

In the past few years, the 5G based IoT has attrack huge number of attentions both in research and industry. It is reported that there will be some early 5G networks (beyond LTE-Advanced) by 2020, full 5G will be available once the standardization process is completed after 2025 [59].

In [9], a novel heterogeneous computing platform was developed for 5G-IoT applications, which matches the needs of service-driving 5G-IoT. In [73, 74, 75, 77], energy harvesting and transfer for spectrum solutions have been proposed. In many works, narrow-band communication issues are addressed: in [76], a new NB-SCMA solution for 5G-IoT uplink communication is proposed to [28, 29, 30]. In [32], Chen et al. proposed a wireless channel model for 5G IoT, which applies wireless big data excavation to provide an efficient active expectation-guaranteed wireless communication scheme. Energy efficiency is an important topics in 5G-IoT. Zhang et al. analysed the energy efficiency in 5G enabled Iot and proposed an integrated architecture was proposed that separately analysed the wireless and wired parts [31].

2.2. 5G enabled IoT

A number of research efforts focused on state-of-the-art research in various aspects of IoT and 5G systems from academics and industry viewpoints [16, 17, 18]. The aim is to offer a venue on the recent advances in theory, application, standardization and implementation of 5G technologies in IoT scenarios. In the past few years, magnificent works on 5G-IoT have been done [16]. The CISCO, Intel, and Verizon have jointly developed a wireless research project on 5G to reveal a novel set of "neuroscience-based algorithms" that adaptive video quality to the demands of the human eye, hinting theat features wireless networks would have built in human intelligence [17].

The 5G can make significant contributions on the future IoT by connecting billions of smart devices to create actual massive IoT, in which smart devices mutually interacting and sharing data without any human assistances [18]. Currently, a heterogeneous domain of applications makes it very difficult for IoT to identify if devices will be capable of satisfying the needs of application [18]. Existing IoT systems widely only use specific application domain, such as BLE, ZigBee, etc. Other technologies, such as WiFi, LP-WA networks, and cellular communications (e.g., MTC using 3GPP, 4G (LTE)), etc. The IoT is constantly and rapidly evolving, with the new proposed technology, and with the existing ones going into new application domain.

Many today's IoT systems are targeting on improving the quality of everyday life, which engages the interconnection between smart home devices and smart environments, such as smart home, smart buildings, or even smart cities. In industry, the Industry IoT (IIoT) is still evolving and facing many challenges, including new requirements for product and solutions and transforming business models [19]. In some critical industry system, such as traffic, machine, etc., the IIoT is still facing many technique challenges, such as the reliabilities, timeless, robustness of connection, etc.

The existing 3GPP and LTE networks are the most engaging communication techniques in the IoT connectivity [72], which offer IoT systems with wide coverage, low deployment costs, high security level, access to dedicated spectrum, and simplicity of management [71]. However, the existing cellular networks are unable to support the MTC communications, which is the ky in the IoT. The emerging 5G networks provides a potentially solution in such a context. The 5G can provide the fastest cellular network data rate with very low latency and improved coverage for MTC communication with respect to current 4G (LTE) offer the potential most demanding IoT applications.

Actually, the M2M communication supports large amounts of smart devices and enables the vision of true connected world.

In the past two years, a number of IoT enabling technologies have been developed. In this review, we classified the works in to following categories:

2.3. 5G IoT Architecture

The 5G-IoT is expected to provide applications with real-time, on demand, all online, reconfigurable, and social experiences, which requires the 5G-IoT architecture should be able to end-to-end coordinated, featuring agile, automatic, and intelligent operation during each phase [7]. The 5G-IoT architectures are expected to provide:

- Provide logically independent networks according to requirements of applications;
- Use cloud based radio access network (CloudRAN) to reconstruct radio access network (RAN) to provide massive connections of multiple standards and implement on-demand deployment of RAN functions required by 5G.
- Simplifie core network architecture to implement on-demand configuration of network functions

Figure 4 shows the architecture of the future international mobile telecommunications (IMT), in which the 5G networks are expected to provide: (1) enhanced mobile broadband (eMBB), (2) ultra-reliable and low-latency communications (uRLLC), and (3) massive machine type communications (mMTC).

3. Requirements in 5G enabled IoT

The IoT is revolutionizing our everyday lives provisioning a wide range of novel applications leverage on ecosystems of smart and highly heterogeneous devices. In the past few years, many research efforts have been made on many challenging topics for the 5G IoT, and the main requirements of IoT include:

- High data rate, the future IoT applications, such as high-definition video streaming, virtual reality (VR), or augumented reality (AR) et al., require higher data rates at around 25 Mbps to provide acceptable performance [7].

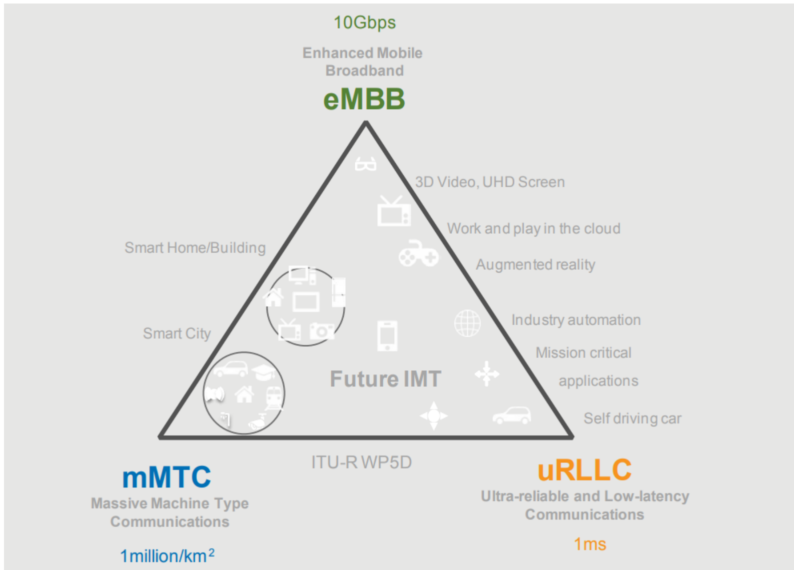

Figure 4: Architecture of future IMT [4]

- High scalable and fine-grained networks, to increase network scalability, the 5G-IoT requires higher scalability to support fine-grained fronthaul network decomposition throgh NFV.
- Very low latency, in 5G-IoT applications, such as tactile Internet, AR, video games, et al., require lower latency at around 1ms.
- Reliability resilience, 5G-IoT requires an improved coverage and handover efficiency for IoT devices and applicaitons users.
- Security, in the future IoT mobile payment and digital wallet applications, different with general security strategy on protect connectivity and user privacy, the 5G IoT requires an improved security strategy to improve the security on the whole network.
- Long battery lifetime, to support billions of low-power and low-cost IoT devices in 5G-IoT, low energy solutions are required by the 5G enabled IoT.
- Connection density, massive number of devices will be connected together in the 5G-IoT, which will require 5G should be able to support the successfuly delivery of message within a certain time and area.

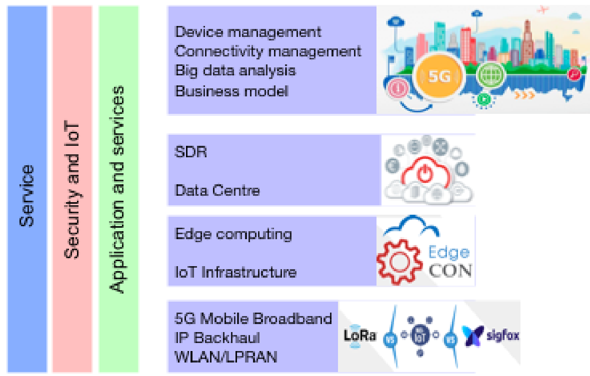

Figure 5: Architecture

- Mobility, the 5G-IoT should be able to support massive number of device to device connectivity with high mobility.

The state-of-the-art of IoT assumes uploading and storing all the raw data generated by IoT devices to the cloud, which will be processed by the cloud servers to extract useful knowledge by using data analysis methods.

4. Key Enabling Technologies in 5G-IoT

The 5G enabled IoT includes a number of key enabling techniques from the physical communication to IoT applications. Figure 6 describes the main technologies associated with 5G-IoT [47]. In this review, we summarized the key enabling technologies into follow five major categories: (1) 5G enabled wireless connectivity; (2) 5G-IoT architecture; (3) devices-to-device communication; (4) 5G-IoT applications; and (5) data and cloud analysis in 5G-IoT.

4.1. 5G-IoT Architecture

The 5G-IoT architecture is one key topic. Figure 7 shows a prototype of smart home that integrated 5G infrastructure, in which the 5G-IoT bridged a number of resource constrained IoT devices to the remote cloud-based applications using multiple of wireless communication protocols.

The 5G-IoT will mainly base on the 5G wireless systems, so the architecture generally includes two plane [12]

- Data plane, focuses on the data sensing through software-defined fronthaul networks

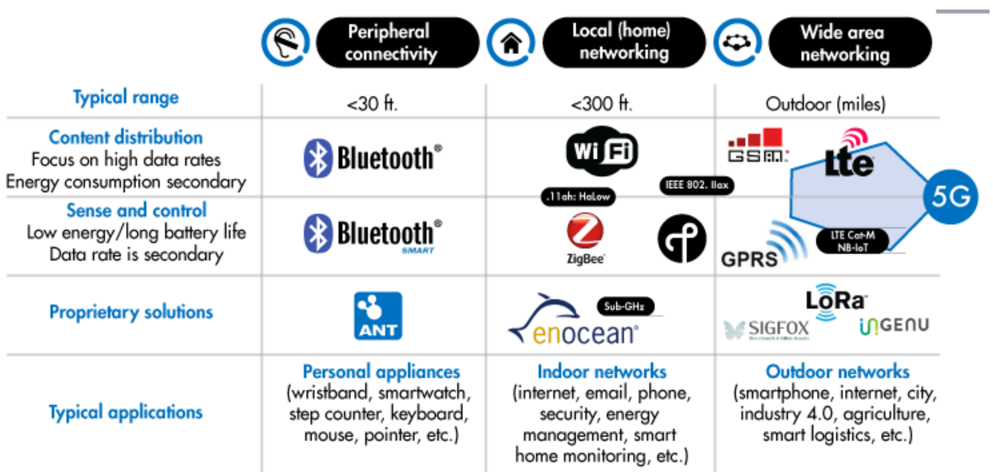

Figure 6: Technologies associated with 5G-IoT [47]

- Control plane, consists of network management tools and reconfigurable services (applications) providers

The 5G-IoT architecture should be able to satisfy the services requirements from following aspects:

- Scalability, cloudification/network function virtualisation (NFV)
- Network virtualization capability
- Sophisticated network management, includes mobility control, access control, and resource efficient network virtualization.
- Smart services provider, the architecture should be able to provide smart services based on the big data analysis.

4.2. Wireless Network Function Virtualisation (WNFV)

As a complementary to the 5G networks, the WNFV will enable the virtualization of entire network functions to simplify the deployment of 5G-IoT, in which NFV will decouple flexible and scalable hardware and underlying network functions to enable 5G-IoT focus on generic cloud servers [11].

The NFV aims to provide scalable and flexible network for 5G-IoT applications, which will enable customized network slicing over distributed cloud to create programmable networks for 5G-IoT applications [15].

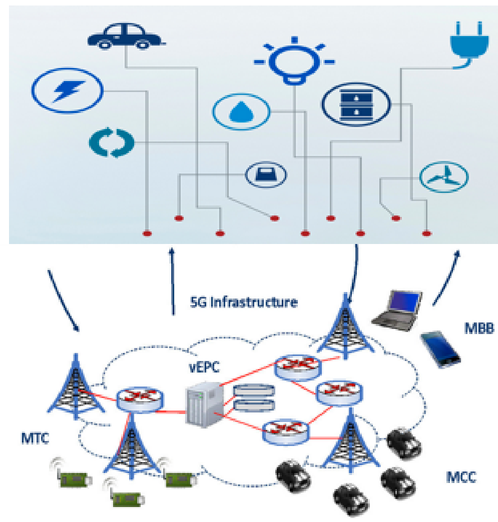

Figure 7: Example of 5G-IoT architecture [7, 12]

The NFV is able to separate a physical network into multiple virtual networks as shown in Figure 9, in which the devices can be reconfigured to build multiple networks according the requirements of applications.

The NFV will provide 5G-IoT applications real-time processing ability by optimize the speed, capacity, and coverage in the logic sliced networks to match the demands of applications. In [1], a 5G-IoT solution is proposed as shown in Fig 10, in which a number of emerging network techniques are applied, such as 5G, LTE-A Pro, M2M devices, and smart IoT, with NFV it is possible to dynamically build networks such as 5G wireless networks, device networks, and 4G networks, depends the demand of applications.

It can be summarized that the 5G NFV will transform the way to to build network in 5G-IoT and will provide a scalable and flexible network functions. The NFV will also significantly enhance the viability radio access network (RAN). An extensive review has been made in [12] for existing NFV solutions.

In the highly heterogeneous 5G-IoT, the network densification will be able to densify 5G infrastructures with multi-RAT connectivity depends the requirements of services from applications.

4.3. Heterogeneous Networks (HetNet)

Heterogeneous Networks (HetNet) is a novel networking paradigm proposed to satisfy the on-demand requirements of service-driving 5G IoT. The

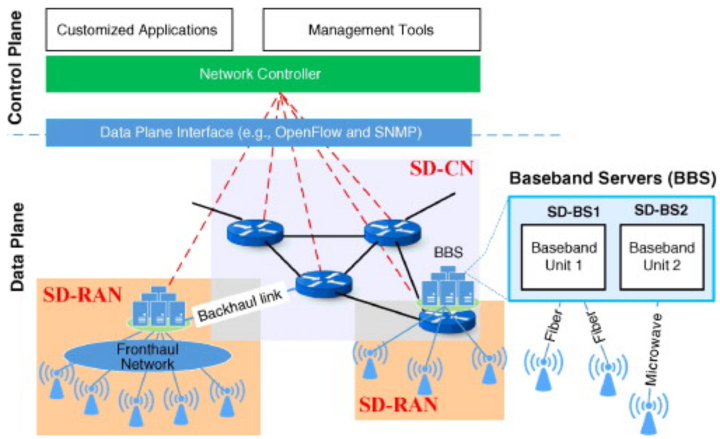

Figure 8: Example of 5G-IoT architecture: SoftAir [7, 12]

Figure 9: 5G NFV technology [15]

HetNet enable 5G-IoT to provide on-demand information transmission rates on demand. A number of 5G Netnet solutions have been developed in recent [45, 46]. The 5G-IoT will deploy massive number of resource constrained devices. To guarantee the QoS for devices in 5G-IoT, a number of HetNet solutions have been proposed: a Massive MIMO based Hetnet has been developed in [46] to build a large-scale MIMO link for backhauling.

M2M communicaiton has been extensively reviewed in [54, 55, 56, 57, 58]. The ETSI standard and applications has been discussed in [54] and [55], in which mobile devices are used as mobile gateways for resource constrained IoT devices. In [56, 57], solutions were proposed to further improve the deployment of M2M applications using 3GPP LTE/LTE-A network.

MTC devices are increasing becoming an intergral part of our lives. Owing to its high data rate support and other salient features, 5G/Hetnets is

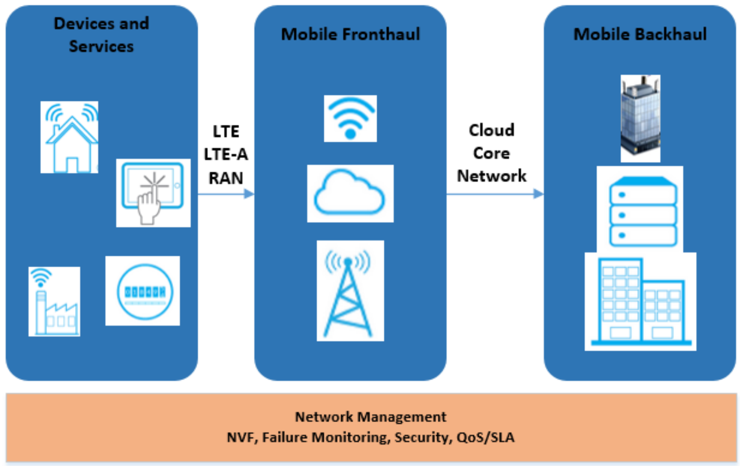

Figure 10: 5G-IoT

being seen as a robust technology solution in 5G-IoT to the fast growing data traffic demands from MTC devices [44].

The HetNet was initially designed for human to human (H2H) communication, while MTC applications are characterized by some unique features such as huge number of devices, high frequency access of network and stringent QoS requiements during emergency situations [45]

4.4. Direct Device to Device (D2D)

In Hetnet, the traditional macrocell base station (MBS) is coordinate to provide low power BSs. However, for the short range communication between two devices (D2D) is proposed as a new way for data transmission, which will benefits the 5G-IoT with low power consumption, load balancing and better QoS for edge users.

D2D enables data exchange between user equipment without the use of Base Station ans serves as an 'Cell Tier' in the 5G-IoT.

In IoT, more than 60% of applications requires low power, long battery, and wide coverage of connectivity. However, the existing technologies, such as Low energy Bluetooth (BLE), WiFi, Zigbee, and 2G/3G/4G cannot support these features. In emerging low-power (LPWA) are gargeting at these applicaitons. In the past few years, a number of new technologies have been developed to match the above needs in IoT, such as LPWA, NB-IoT, longrange (LoRa), SigFox, Long Term Evolution category M1 (LTE-M), etc.

Among them, the LTE-based NB-IoT released by 3GPP is becoming a leading technologies and have attracted many attentions from both acadamic and industry. In short range wireless communicaiton (less than 200 meters), the device-to-device (D2D) communication is becoming a leading technology that can provide lower power and QoS guarantted communication for massive device communicaiton. The D2D is employed as an extension to NB-IoT uplinks that can establish routing cellular link through NB-IoT. In IoT, D2D is used by cooperation with mobile NB-IoT user equipment.

Meanwhile, the D2D is expected to improve energy and spectrum efficient in 5G-IoT. In [66], to improve the spectrum efficiency of uplink spectrum a D2D pair reuse solutin is proposed. In [67], a NB-IoT and LTE standard integration solution is proposed aimed at improving trust-based solution for D2D to assist in relaying IoT traffic to the NB-IoT BS.

The D2D communication is expected to enable novel unprecedented opportunities for P2P and LBS applications in 5G-IoT, however, introducing D2D in 5G-IoT will pose a number of challenges and requires updates to the longstanding cellular architecture [68].

4.5. Advanced spectrum sharing and interference management

From the 5G-IoT architecture described in 7, a massive number of 5G IoT devices will be densely deployed in many cases to guarantee the coverage and traffic load imbalance. As a result, the spectrum sharing and interference management is a key enabling technology of 5G-IoT. The HetNet is a promising solution for interference management in 5G IoT.

Massive MIMO are at the heart of achieving higher spectrum efficiency. In recent, a number of advanced MIMO techniques have been proposed, including multi-user MIMO (MU-MIMO), very large MIMO (VLM) etc. The 3GPP LTE-A alrealdy included MU-MIMO, which can significanlty improve network capacity by leveraging higher number of antennas at the BS [69].

4.6. Other Enabling Techniques in 5G-IoT

Furthermore, Machine-Type Communications (MTC), millimiter Wave (mmWave), mobile edge computing, Software Defined Networking (SDN), Network Function Virtualization (NFV), and Narrowband IoT (NB-IoT) are all expected to play a fundamental role for the IoT in future 5G systems.

Other key enabling techniques include: optimization methods in 5G IoT, which include convex optimization, heuristic methods, evolutionary algorithm (EAs), machine learning methods, and artificial neural networks (ANNs). These methods will make increasing impact to key enabling techniques.

5. Research Challenges and Future Trends

The 5G provides features that can satisfy the requirements of the future IoT, however, it also opens new set of interesting research challenges on the architecture of 5G-IoT, trusted communications between devices, security issues, etc. The 5G-IoT integrates a number of technologies and is creating significant impact on applications in IoT. In this section, we will review the potential research challenges and future trends in 5G-IoT.

5.1. Technical Challenges

Although many research efforts have been made on 5G-IoT, there are still technical challenges:

1. 5G-IoT architecture is a big challenge, as addressed above, a number of architectures have been proposed with many advantages, however, the architecture design still impose many challenges, include
    - **Scalability and network managemen**t, in the 5G-IoT the network scalability is a major issues due to the massive number of IoT devices. managing the state information of massive number of IoT devices is also an issue that needs to be considered [62, 63].
    - **Interoperability and Heterogeneity**, seamlessly interconnection between heterogeneous networks is a major challenge. Massive number of IoT devices to be connected through a communicaiton technology to communicate, disseminate, and collect vital information with other smart networks or applications [64, 65].
    - **Security assurance and Privacy concerns**, security and cyberattack, increased privacy concerns
2. **Wireless software defined network** (SDN), the effectiveness for 5G data networking is still a challenge. While bring the scalability, there are still technical gaps that need to be closed in SDN. (1) To provide the core network with highly flexibility, the scalable SD-CN is a challenge for network scalability. (2) The separation of control and data plane is difficult for most SDN.

3. The **NFV** is highly complementary to the SDN, but not dependent on it. In the past few years, a number of NFV solutions have been developed, including SoftAir [11], OpenRoads [12], CloudMAC [14], SoftRAN [**?**] et al. There are several technical challenges need to be fixed in 5G-IoT: (1) energy-efficient network cloudification; (2) Security and privacy, VNFs runs on third-party public clouds as a result the security and privacy become a big concern. (3) VNFs management, efficient VNFs switch systems and interfaces provided by VNFs are two technical challenges in NFV.
4. **D2D communication** are expected to provide high throughput for 5G-IoT. In D2D, the energy and spectral efficiencies are two challenges. The successful of D2D needs a well spectral resource and interference management scheme to maximum the through and provide high reliability over communications between device to device.
5. **Deployment of IoT applications** is challenging due to its large scale, resource limited devices and heterogeneous environment. Many existing IoT applications consist of overlaid deployments of IoT devices networks where both the devices and applications are unable to interact and share information each other. Meanhile, the capability and effitiency to collect and disseminate data in the physical world are are challenging. In [78], a multilevel and multidimensional service provision platform is proposed for IoT that addresses both the above described challenging issues.
6. There are still several challenges need to be fixed such as dense heterogeneous networks deployment in IoT, multiple access techniques for 5G and beyond 5G networks, full-duplex transmission at the same time, etc.

5.2. Security Assurance and Privacy Concerns

In the next 5G-IoT, critical new security capabilities will be needed at the device and network levels to address complex applications including smart city, smart networks, etc. In the diverse 5G-IoT system, the security is very complicated. The designer must consider not just software intrusion from afar, but also local intrusion at the device itself [52]. Meanwhile, the security assurance must consider avoid weak security links .

- Identity

- Authentication
- Assurance
- Key management
- Crypto algorithm
- Mobility
- Storage
- Backward compatibility
- Assurance

5.3. Standardization Issues

Large amounts of IoT solutions will be proposed in the 5G-IoT. Standardization of 5G-IoT will make the implementaion and development of applications easier. Due to the diverse nature of networks and devices in 5G-IoT, there is a lack of consistency and standardization for both IoT systems and applications. There are still many hurdles and chanllenges in implementation of these solutions [70]. The hurdles facing 5G enabled IoT standardization can be grouped into following four categories:

- IoT devices, namely platform, include the form and design of IoT products, big data analytic tools, et al.
- Connectivity, includes communicaiton networks and protocols that connect IoT devices.
- Business models, which are expected to satisfy the requirements of e-commerce, virtical, horizontal, and consumable markets.
- Killer applications, include control function, data collection and analysis functions.

The standardization of 5G IoT involves two types standards: (1) technology standards, including wireless communication, network protocols, data aggregation standards; and (2) regulatory standards, including security and privacy of data, such as general data protection regulation (2018), security solutions, cryptograpic primitives, et al. Challenges facing the adotion of standards within 5G-IoT are, unstructured data, security and privacy issues data analysis protocols, etc.

The 5G-IoT is a very complex ecosystem, which is able to bridge the gaps between the human and the environment around. The "IoT as a service" might be a possible outcome of future standardization [70].

5.4. Research Trends

The evolving 5G is staill it an early stage. In addition to address the above challenges, we identify following research trends as:

1. In 5G-IoT, applications will continue to expand, more and more devices will be conneced and full potential of the IoT is still being realized. 5G-IoT applications have motivated an on-demand for feasible network architecture, as named data networking (NDN) to support the high density IoT applications [48]. Since the diverse nature of IoT, the 5G-IoT will be increasingly fragmented and more sophisticated technologies, such as NVFs, will be developed to manage the 5G-IoT.
2. The edge computing is another key use cases in 5G-IoT, which will focus on following two aspects: (i) the analytics revolution, edge computing and 5G networks will drive the the IoT devices be the core of the IoT; (2) the edge computing in 5G-IoT will significantly boost high computation related applicaitons, such as VR/AR or myriad data-intensive smart citives initiatives, storage, et al.
3. The convergence of 5G, AI, data analytic and IoT [53]. The combination of four key technologies are poised to transform the 5G-IoT and will enhance user experiences for communications, applications, digital content, and commerce. The AI will enable 5G-IoT be able to cognitive, new applications, such as connected automotive, consumable IoT, connected homes, wearable, and variable-reality. 5G will make the future IoT smart. Advanced analytics and machine tools will be developed to help management.
4. Spectrum and energy harvesting efficient reserach will be an other key research trend in 5G-IoT systems as mentioned in [49, 50] in spectrum sharing cellular 5G networks. Low energy consumption IoT devices will make significantly extend the scalability of IoT, meanwhile the spectrum solutions will enhance the coverage and fast switches between the wireless networks using 5G technology.

5. Security and privacy concerns are always the key research trend both in existing IoT and future IoT solutions. 5G security and privacy solutions in IoT will cover all layers of the 5G-IoT, includes the end-to-end protection mechanism, protection of identity and location privacy against active attackers. The fast-growing needs in security of 5G-IoT include secure infrastructure, trust models, service delivery models, increased privacy concerns, and threat landscape.
6. Context-aware IoT Middleware Solution, in the high device density scenarios the context-aware solutions are expeced to increase the scale, mobility, and heterogeneity of entites in IoT, which could be autonomous and automatically adapt to dynamic changes in context.

5.5. Security assurance and Privacy concerns

Security and privacy concerns include authentication, authorization, device access control, and privacy preserving in 5G-IoT. Existing 3GPP networks focus on functional node specification and abstract interfaces. However, in 5G-IoT, the 5G networks will serve as core infrastructure than 4G or 3GPP, security assurance will be a key challenge. Currently, there is not a completely new development. The 3GPP is required to extend security specification.

- Trusted communications over 5G networks in the presences of eavesdroppers will be a challenging research trend. Although security in IoT was viewed as a high-layer problem to be solved using cryptographics methods, the device security is emerging as a promising way of defense to realize 5G-IoT.

- Flexible and scalable security architecture, from the physical layer to the new business models, the security architecture will focus on new trust model and identity management, service-oriented security, security assessment, low-delay mobility security, and user privacy protecitons.

- Energy-efficient security, 5G-IoT envolves billions of resource constrained devices, which are uanble to employ computational security solutions, as a result, the lightweight security solutions over the resource constrained devices will be a key research trend.

Instead of individual security mechanisms, a systematic security and privacy protection stragegy is needed to in 5G-IoT, and more valid security approaches, such as trust models, device security, and data assurances are still to be revisited. The cyber attack will target user device, access and core networks, home and external networks, which drive researchers to develop more sophisticated solutions against cyber attacks or cyber crimes.

6. Conclusion

The 5G-IoT integrates the emerging 5G techniques into future IoT. This paper reviews the recent research on both 5G and IoT. We firstly introduce the background and current research on 5G and IoT. Then, we analyse the new requirements in 5G enabled IoT. Afterwards, we detailed the key techniques in 5G-IoT and analysed the challenge and trends of the future IoT.

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