Big Data Challenges in 5G Networks

Salman Rashid
Faculty of Computing and Engineering
Universiti Teknologi Malaysia
Johor Bahru, Malaysia
rashid.salman@graduate.utm.my

Shukor Abd Razak
Faculty of Computing and Engineering
Universiti Teknologi Malaysia
Johor Bahru, Malaysia
shukorar@utm.my

***Abstract*—** Now a days, world is witnessing a huge flood of data due to ever growing heterogeneous traffic, mobile network subscribers and online services. This trend is evolving continuously at a rapid pace and diversely in the form of big data. Wide range of use-cases scenarios with diverse requirements brings huge challenges for 5G. One of the most important requirements for use cases is high scalability, ubiquitous connectivity with low latency and high data rate with optimal energy, are equally important in 5G. Big data analytics is required to process this huge amount of raw data and extract small sized and useful information. This information can be used by arbiters to make consistent decisions. The paper presents challenges of 5G technical scenarios, big data perspective and emerging technologies of 5G. This paper also provides a detailed overview of big data challenges, imminent in achieving 5G goals.

Keywords—connection density; big data analytics; traffic volume

I. Introduction

Characteristics of 5G include extremely low latency, high speed data transfer and world-wide connectivity. These characteristics makes 5G agile to perform broad set of application scenarios: from high user mobility to pervasive video, from ultra-reliable to tactile Internet communication, from broadcast like services to massive internet of things (mIOT), from lifeline communications to broadband access everywhere. For enabling such diverse applications, ruthless improvements in 4G network is required: more connected devices (10-100 times), higher data rates (10-100 times), less latency (1ms), availability (99.999 %) [1], longer battery life (10 times), higher mobile data volume (1000), network management operational expenses (5 times less), energy consumption (10 times less) [2]. Field trial design and classic manual approaches are impractical due to new eco system where heterogeneous networks are expected to increase tremendously [3]. The 5G radio access and core networks need orchestration of its resources and to control the network efficiently, flexibly and with scalability, 5G networks will be based on SDN/NFV infrastructures.

Currently, during normal operations by management and control functions a huge amount of data is already generated in 4G networks and expected more to come in 5G networks due to heterogeneity in layers, diversification process and technologies, the additional management and control complexity increases in SDN and NFV architectures, due to the initiation of internet of things and machine to machine (M2M) paradigm [4]. With the advent of such technologies, increase in variety of services and applications with different traffic patterns and quality of service/ quality of experience requirements. The time sensitive multimedia and highly bandwidth intensive services over the 5G networks bring new challenges, constraints and problems not encountered in 4G networks.

A. Potential of 5G

The functionalities and architecture of future 5G networks are expected to be agile in order to accommodate the heterogeneous requirements (latency, reliability and bandwidth) of 5G applications [5]. The expansion of the service scope of cellular networks includes a wide range of services such as mission critical machine type communication, Internet of things and mobile broadband has evolved towards 5G and beyond systems [6]. In 5G internet protocol (IP) is expected to reach about 20 Gbps per sector with ultra large content traffic. This ultra large content traffic will travel fast on the wired and wireless network. The low band spectrum is essential for various scenarios such as high mobility and seamless coverage as required in massive Machine Type Communication (mMTC) and ultra-Reliable Low Latency Communication (uRLLC). When enhanced Mobile Broadband (eMBB) is mature it will offer data rates of up to 20 Gbps and high number of users will experience data rates of 100 Mbps [7]. To handle vertical services, with storage, connectivity and communication solutions, 5G must be transformed radically, designed for a precise digital business case of different industries (e.g. energy, automotive, health care, and multimedia). To provide services to users keeping the same cost that user is paying today is set to be a serious challenge for mobile operators and vendors. As the expected data traffic is 1000x in the coming era. Wireless industry is facing a strange challenge. It has to improve infrastructure to 1000 times, without increasing the CAPEX and OPEX [8].

Data rate requirement for various applications shown in Fig 1, are different in 5G networks. 5G support verity of use case where as demand of data rates is also variable in each scenario. Data rate requirement for smart grids for switching windmills ON/OFF and control automation is between 10 Kbps to 1.5 Mbps. For factory automation where E2E data rate requirements are 1 Mbps for smooth and efficient working. As far as intelligent transport system is concerned the data rate expected from 5G is between 10 Mbps to 700 Mbps. The reason for such a high data rate is due to its safety and high connectivity with extremely low latency. Healthcare services include tele-diagnosis, tele-surgery, tele-rehabilitation its requirements for data rate is 100 Mbps with low latency. In near future, robots will be going a lot of jobs such as communication infrastructure, construction and maintenance in dangerous areas. So, the data rate requirements for robotics is 100 Mbps. Whereas, serious gaming, virtual reality and education and culture requirements for data rate is astonishing at 1Gbps. Extremely high data rate requirement is due to its applications in various areas and its sensitivity and high precision of the object manipulation.

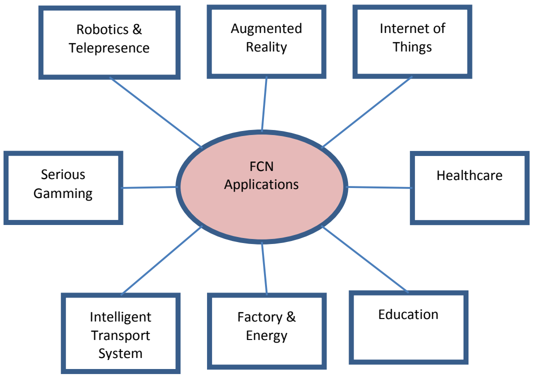

Fig 1: Future Communication Network (FCN) application

Latency requirements for various applications are different in 5G networks. 5G support verity of use case where as demand of latency is also variable in each case. For factory automation where E2E latency requirements are between 0.25 ms to 10 ms for smooth and efficient working. In near future, robots will be going a lot of jobs such as communication infrastructure, construction and maintenance in dangerous areas. So, the latency requirement for robotics is 1ms. Healthcare services include tele-diagnosis, tele-surgery, tele-rehabilitation its requirements for latency is 1 ms to 10 ms. Latency requirement for smart grids for switching windmills ON/OFF and control automation is between 1 ms to 20 ms. As far as intelligent transport system is concerned the latency expected from 5G is between 10 ms to 100 ms. The reason for such a low latency is due to its safety and high connectivity. Serious gaming, virtual reality is at astonishing1ms. Whereas, education and culture requirements are at 5 ms to 10 ms [9].

5G provide support and offers various scenarios For Device to Device (D2D), 5G provides built-in support for D2D, ad-hoc D2D communication, deals local traffic directly and beamforming to reduce interference. For Machine to Machine (M2M) 5G can resolve time critical applications. Architecture of CRAN and SDN relaxes tight coupling of user plane and control plane. Internet of things (IoT) is proliferating exponentially. 5G offers connection density, massive data, distinct architectures, multiplexing, extended coverage area, high throughput, extremely low latency and secure. Internet of Vehicles (IoV), to accommodate time critical and to provide extremely reliable IoV 5G offers efficient traffic management through small cells for its management with dedicated links. For its computing 5G offers cloud capabilities, to distribute contents use content-centric networking with extremely low latency, efficiency and agility. In smart cities and grid, 5G provides a much better support in terms of greater spectrum availability/efficiency, longer battery life of its nodes, highly directional antennas, high coverage area, low infrastructure cost, low latency and huge data rates.

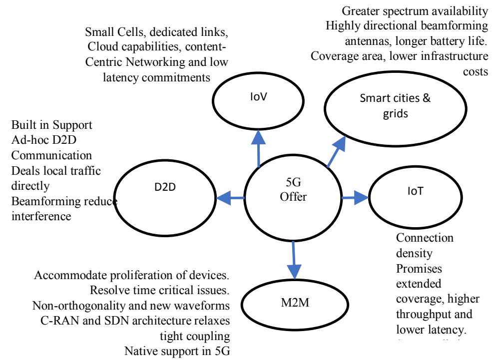

Fig 2: 5G offers support for Use cases

B. *Heterogeneous Demand of 5G Cellular Network*

Although 5G is still being very much in development phase but it is expected to provide services as per requirement and accommodate use cases shown in Fig 2, in terms of latency, reliability and bandwidth. It is obvious that with the inclusion of machine type communication and human type communication, brings considerable differences in terms of energy consumption, traffic pattern and packet size [10]. Next generation cellular networks has to face heterogeneous characteristics of applications and unique and unknown quality of service requirements [11].

II. CHALLENGES OF 5G

A. *CAPEX, OPEX and Performance Challenges*

To avoid underutilization along with keeping the cost efficiency is a tradeoff to rethink, this pose a complex challenge in requirements for infrastructure capacities of 5G networks. Well-designed cost model is required to consider QoS parameters such as latency, data rate, mobility, jitter, priority, etc. Along with these parameters, cost model should account the features of backhaul and fronthaul links of the networks that can influence in cloud and core mobile network. Cost model definition should be able to distinguish between active resources in cloud and distributive mobile core. To guarantee configurability, flexibility and customization, the expected performance in terms of key performance indicators (KPIs) of 5G, there is a need investigate performance of virtualization and softwarization in 5G environments.

B. *Core Network Challenges*

In service based 5G core network deployment and management of network functions are still a big challenge. It is difficult to manage and balance among load and demand in congested urban areas for future 5G networks Fig 3. Management of a network is critical for reliability, service availability and resiliency of networks. For real time services dependencies of entities and network topology evolution is unpredictable in network. The management system must consider the real time change in topology to identify the faulty component and to avoid incorrect and obsolete results. Latency is the undoubtedly one of the key problems to overcome in 5G scenarios. This results in exceptional challenges in terms of increasing traffic and diverse requirements of a mobile network.

- Due to the explosion of massive traffic and introduction of new radio access technologies create a bottleneck for mobile network converted to radio interface towards the core networks and backhaul.
- Machine to machine and human to machine communication needs very low data rates and significantly non-sensitive to latency but the number of interconnections is extremely high. Thus, it makes the core network suffer from signaling storm.
- Vertical industries have a huge expectation from mobile networks, such as industrial automation, autonomous driving etc. vertical industries requires low latency and extremely high reliability.
- Due to constantly altering network topologies and operating conditions, efficient methods are required to achieve stability and reliability of networks without increasing operational cost.
- It is extremely challenging to manage future complex networks, related to ultra-dense deployments, applications, heterogeneous nodes, applications, due to diverse RANs simultaneously exists in the same setting.
- To cover all the use cases and support different network software/hardware suppliers, an orchestration system flexible and efficient needs to be implemented.
- New management functionality integration with existing OSS/BSS systems.
- Need to improve energy efficiency to support 10x users and 1000x traffic.
- Need to reduce latency for better user experience by enabling Gbps speeds.
- New virtualized architectures are required to manage such diverse features of 5G.

It is difficult to manage highly dynamic networks, where service providers might not have full control of the deployment of nodes such as femto-cells deployment by end users, active antennas, fluctuating number of nodes needs energy saving policies etc. Due to the complex dependencies and magnitude of tunable parameters, the complexity and large scale of future radio access technologies enforces considerable management and operational challenges.

Complex architecture and massive amount of data travelling over a future network, big data, in urban areas. Explosion of massive data is no exemption due to a diverse range of connected devices. Big data composition will include textual content such as unstructured, structured and semi-structured, to multimedia content such as audio, video, images etc. on multiple platforms such as sensor networks, IoT, cyber-physical systems, social media and machine to machine communications. This diverse composition is capable of generating and consuming quintillions of bytes of data. Video data is dominated among different kinds of data traffic. Video data has already offered very extensive challenges to wireless mobile networks and similarly challenges for 5G are even steeper. For a single Virtual reality traffic is expected to reach at 10 Gbps. Similarly, High Definition (HD) videos are becoming even more significant for mobile devices. With such a complex and heterogeneous data raining from any-where, any-time and any-device, is undoubtedly an era of Big Data. Control and management of such a data will be a huge task on hand. Big data can be defined as volume, variety and velocity of data that provides significant prospects for cost-effective decision making and enhance insight from extraction of information and knowledge from data [12].

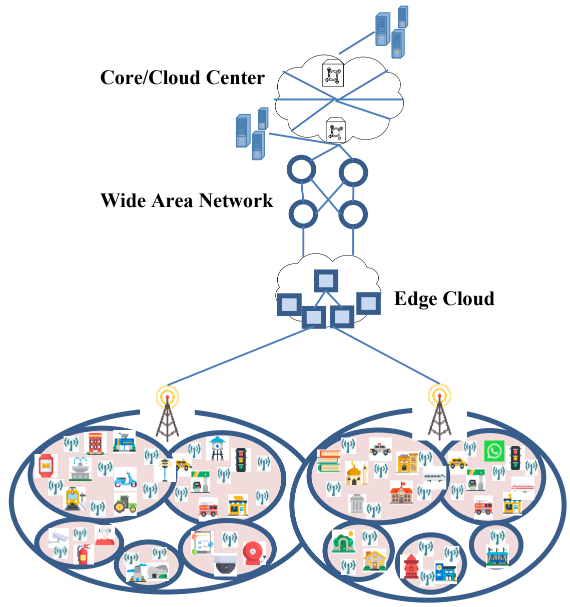

Fig 3: Basic Architecture of 5G

As big data is growing rapidly in wireless networks, to efficient manage the wireless network big data analytics is becoming the backbone of the wireless communication.

Modern data analytics algorithms are applied to handle and extract knowledgeable insights from such a massive data source. Firstly, massive amount of data will be collected from homogenous sources, then preprocessing and using network resources will be send to data centers where various data analytic techniques such as descriptive, predictive and prescriptive analytics will be performed to extract meaning-full knowledge [13]. Descriptive analysis uses mainly visualization tools to get insights on of the raw data to extract, the network performance, traffic profile, mobility pattern, measure key performance indicators (KPIs) etc. Predictive analytics is a remarkable tool for making predictions. Predictive analytics can only produce forecasting about what might happen. Prescriptive analytics goes steps ahead of just predicting the future events by suggesting decision options for slicing, virtualization, edge-computing and caching, along with the implications of each decision. Therefore, the prescriptive analytics need an efficient predictive model, actionable data and a feedback system for tracking down the results generated by the model. Predictive and prescriptive analytics used machine learning, data mining, and stochastic modelling are performed to extract knowledgeable data for cognition and training of next generation networks. Following are the challenges of 5G big data.

III. BIG DATA CHALLENGES

It is not easy to deal with big amounts of data especially if there is a certain goal in mind since data arrives in fast manner, it is crucial to provide processing speeds, sorting and fast collection of data [14]. The data distribution is about to change with time, it is challenging to process non-stationary time series data. Due to the multidimensionality, dynamicity and complexity of heterogeneous devices with diverse services and data, it is challenging to develop a computational model or framework that can collect, discover, mine, analyses and process affective data along with healthcare big data timely and with the best accuracy. The services will receive huge data volumes from large number of users and generate substantial load on the next generation networks. The process of extraction useful, valuable patterns and hidden information from big data is called big data analytics. Advanced analytics techniques are applied on large data sets to depict emerging opportunities and knowledgeable extraction of data.

A. Data Process and Management

To manage and process huge amount of data is challenging [15] in terms of designing of algorithm capable of effective and dynamic processing of resizable data and exploiting insight of data.

- Data itself i.e. data volume, variety, velocity, veracity, value.
- Process challenges: capture data, integrate data, transform data, selection of right model for analysis, provides results.
- Sensor data requires storage and analysis due to increasing volume. It is also needed to improve the response time and efficient energy consumption for better network lifetime.
- Data analytics efficiency in cost effective and green fashion.
- Cover management challenges such as security, privacy, governance and ethical aspects.
- Redundant data, generated in certain areas due to user mobility pattern, but other areas suffers from lack of resources. Hence, device management and data acquisition process are critical.

1) *Data Acquisition and Warehousing* is a challenge of gathering data from diverse sources and storing data. The integral complexity of Big data and due to the explosion of traffic and number of devices, bring unprecedented problems such as acquisition and storage.

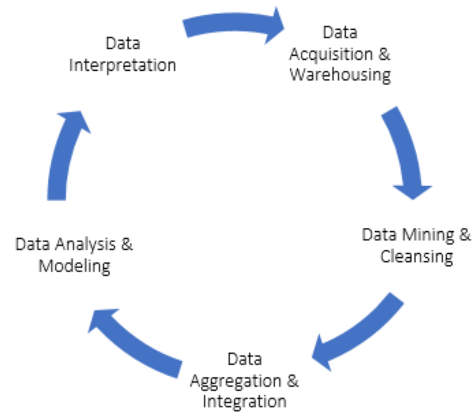

Fig 4: Process Challenges of Big Data

2) *Data Mining and Cleansing* is related to extraction and cleaning of data from big data. It has its own challenges such as identifying a better way to mine and big data cleaning can have a great value and impact.
3) *Data Aggregation and Integration*, once data is mined it is needed to aggregate similar data and integrate data to remove redundancy and repetitions i.e. tweets re-tweets etc. improved decision making and creating new knowledge is remains a key challenge.
4) *Data Analysis and Modeling,* process begun when data is acquired, stored, mined, cleaned and integrated. It is challenging to extract knowledgeable information from big data which is often unreliable, noisy, heterogeneous and dynamic in nature.
5) *Data Interpretation* is finding the real sense of extracted knowledge and to make appropriate decisions is performed in the process of data interpretation. It is relatively easy step like visual data representation and making data understandable to users. Fig 4 shows the process challenges of big data.

B. Bussiness Intelligence

In business intelligence network is supposed to optimize its resources and services to save its cost while providing visibility and flexibility of supply chain and resource allocation. Challenges in business intelligence are lack of sufficient resources and skilled persons, data integration complexity, privacy issue and data security, insignificant data warehouse architecture and inadequate infrastructure and synchronizing large data.

C. Complexity

Complexity of big data is a challenge in terms of correlation, connectivity of data and relationship. It can further evident in terms of multiple data hierarchies and linkages.

IV. RELIANCE OF 5G ON BIG DATA

5G accommodate verity of services, can handle diverse use cases and future applications that are yet to come. This massive agility and flexibility of 5G brings massive data, 'big data'. Table 1 is categorized in terms of characteristics of 5G with its upheld challenges.

- ***Data Density*** As number of devices increases it brings huge flood of data and saturates network. Dealing with such huge amount of data presents its own challenges for 5G.
- ***Traffic Diversity*** different application/users requires different and diverse requirements.
- ***Connection Density*** billions of devices needed to be connected with the 5G network.
- ***Heterogenous Sources*** data is not only huge but also this massive data is diverse in nature.
- ***Complex Architecture*** 5G claims of uRLLC, eMBB, makes its architecture complex hence, variety of challenges,
- ***Ultra-Low Latency*** many future applications require extremely low latency, it is challenging for 5G to achieve such an extraordinary requirement successfully.
- ***Reliability*** it is important for mission critical services. It is challenging to reduce COPEX and OPEX along with admirable E2E delivery while keeping reliability at 99.999%.

TABLE I. Challenges of Big Data in 5G

CHARACTERISTICS	**CHALLENGES**	
DATA DENSITY	• Multi-tenancy service-oriented environment • Extraordinary increases performance expectations • Management of cache size	• Congestion due to huge data • Bottleneck shifted towards backhaul and core network • Proactive caching framework
TRAFFIC DIVERSITY	• Diverse Requirements • End-user QoE and service provider's profit	• QoS levels and SLA • Performance degradation of path heterogeneity
CONNECTION DENSITY	• Low-power massive-connections • Congestion due to massive connectivity • High capacity hotspot	• Small cells may be heavily loaded, and new small cells may not be added to the system
HETEROGENEOUS SOURCES	• Heterogeneous resources for different slices • Diversified Key Performance Indicators (KPI)	• Congestion due to huge data • Network resource sharing will be achieved in terms of QoS Parameters
COMPLEX ARCHITECTURE	• Location base deployment • Complexity of network elements • Demand for new use cases in design challenges • Flexible allocation of resources	• Small cells may be heavily loaded, and new small cells may not be added • End-to-end services in multiplatform 5G environment
ULTRA-LOW LATENCY	• Caching redundancy and intra cache communication • QoS requirements are time bounded. • Wireless multimedia services are time-sensitive	• Trade-offs capacity versus latency, storage versus link load • Requirements of ultra-real-time services
RELIABILE	• Reducing CAPAX and OPEX • QoE of users and resources utilization	• Management and orchestration of heterogeneous resources • Low latency
HIGH MOBILITY	• Resource allocation and network slicing	• Intelligent mobility in smart cities
RESILIENCE	• Detection and location of failures and its performance	• Handling of anomalies
FLEXIBILE	• Optimized utilization of the heterogeneous back hauling networks • Efficient and flexible orchestration system	• Network slicing configuration with high accuracy and low price
AREA COVERAGE	• Seamless wide-area coverage	
SCALABLE	• Management and deployment of network • Scalable at cluster level to overcome potential bottlenecks • Radio resource virtualization • QoS parameters	• Integration of the new management functionality with existing OSS/BSS systems. • Scalability of the user plane is neglected only focus on control plane • VNF placement
SECURE	• Security and integrity of SDN/NFV environments for function migration	• Development & implementation of a security system for 5G trust model
eMBB	• Internet service with diverse requirements. • Mechanism for Internet access service	• Enhanced optimization

- ***High Mobility*** handoff occurrence and providing services to users even moving at high speed such as trains, cars etc. is challenging.
- ***Resilience*** 5G must accommodate and tolerate network nodes failure while responding to user requirements without any lags.
- ***Flexibility*** to integrate fronthaul and backhaul with backward compatibility/support.
- ***Area Coverage*** to connect > 95% of users with 5G, experiencing same QoS is challenging.
- ***Scalability*** 5G must be scalable to ensure connectivity with billions of devices. Scalability presents massive challenges for the success of future networks.
- ***Secure*** it is always a risk of security threats and attacks in any systems. With 5G this risk is even more due to heterogeneous sources, data diversity and connection density.
- ***Enhance Mobile Broadband (eMBB)*** with IoT, machine to machine, IoV, smart grid, mobile users and numerous other scenarios. It is challenging to optimize and provide highly diverse and dense services to future applications/scenarios.

V. Conclusion

In 5G, the intention is moved towards meeting the potential of micro cells, millimeter wave spectrum, massive MIMO with high data rate requirements. Whereas the goals of 5G networks are handling of big data at low cost, low latency, reliability, scalability, area coverage and enhanced mobile broadband. To accomplish these goals requires upgraded technologies with intelligent decision-making capabilities, cache content delivery protocols, orchestration framework, backward technology support, edge/cloud computing, security frameworks and newer architecture designs. 5G network will be complex as compared to legacy networks, apart from its complexity, 5G networks will be smarter and more intelligent in terms of resource distribution, cost efficiency, load balancing and network management. Ultra-Reliable Low Latency Communication (uRLLC) are important factors for QoE in next generation communication systems.

Acknowledgment

We gratefully acknowledge the financial support provided by the Universiti Teknologi Malaysia (UTM), through grant: Q.J130000.2513.20H60.

References

[1] D. Marabissi *et al.*, “A Real Case of Implementation of the Future 5G City,” *Futur. Internet*, vol. 11, no. 1, p. 4, 2019.

[2] M. Bärring *et al.*, “5G Enabled Manufacturing Evaluation for Data-Driven Decision-Making,” *Procedia CIRP*, vol. 72, pp. 266–271, 2018.

[3] J. Moysen and L. Giupponi, “From 4g to 5g: Self-organized network management meets machine learning,” *Comput. Commun.*, 2018.

[4] M. Condoluci and T. Mahmoodi, “Softwarization and virtualization in 5G mobile networks: Benefits, trends and challenges,” *Comput. Networks*, vol. 146, pp. 65–84, 2018.

[5] Z. Frias and J. P. Martinez, “5G networks: Will technology and policy collide?,” *Telecomm. Policy*, vol. 42, no. 8, pp. 612–621, 2018.

[6] I. F. Akyildiz, A. Kak, E. Khorov, A. Krasilov, and A. Kureev, “ARBAT: A flexible network architecture for QoE-aware communications in 5G systems,” *Comput. Networks*, vol. 147, pp. 262–279, 2018.

[7] A. Morgado, K. M. S. Huq, S. Mumtaz, and J. Rodriguez, “A survey of 5G technologies: regulatory, standardization and industrial perspectives,” *Digit. Commun. Networks*, vol. 4, no. 2, pp. 87–97, 2018.

[8] A. Santoyo-González and C. Cervelló-Pastor, “Latency-aware cost optimization of the service infrastructure placement in 5G networks,” *J. Netw. Comput. Appl.*, vol. 114, pp. 29–37, 2018.

[9] I. Parvez, A. Rahmati, I. Guvenc, A. I. Sarwat, and H. Dai, “A survey on low latency towards 5G: RAN, core network and caching solutions,” *IEEE Commun. Surv. Tutorials*, 2018.

[10] M. Bennis, M. Debbah, and H. V. Poor, “Ultra-reliable and low-latency wireless communication: Tail, risk and scale,” *arXiv Prepr. arXiv1801.01270*, 2018.

[11] Y. Hao, D. Tian, G. Fortino, J. Zhang, and I. Humar, “Network Slicing Technology in a 5G Wearable Network,” *IEEE Commun. Stand. Mag.*, vol. 2, no. 1, pp. 66–71, 2018.

[12] Y. Qiao, Z. Xing, Z. M. Fadlullah, J. Yang, and N. Kato, “Characterizing Flow, Application, and User Behavior in Mobile Networks: A Framework for Mobile Big Data,” *IEEE Wirel. Commun.*, vol. 25, no. 1, pp. 40–49, 2018.

[13] M. G. Kibria, K. Nguyen, G. P. Villardi, O. Zhao, K. Ishizu, and F. Kojima, “Big Data Analytics, Machine Learning and Artificial Intelligence in Next-Generation Wireless Networks,” *IEEE Access*, 2018.

[14] Z. Chang, Z. Zhou, S. Zhou, T. Chen, and T. Ristaniemi, “Towards Service-oriented 5G: Virtualizing the Networks for Everything-as-a-Service,” *IEEE Access*, vol. 6, pp. 1480–1489, 2018.

[15] T. Norp, “5G Requirements and Key Performance Indicators,” *J. ICT Stand.*, vol. 6, no. 1, pp. 15–30, 2018.