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Correlation between Terms of 5G Networks, IoT and D2D Communication

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ABSTRACT

The proliferation of heterogeneous devices connected through large-scale networks is a clear sign that the vision of the Internet of Things (IoT) is getting closer to becoming a reality. Many researchers and experts in the field share the opinion that the next-to-come fifth generation (5G) cellular systems will be a strong boost for the IoT deployment. Device-to-Device (D2D) appears as a key communication paradigm to support heterogeneous objects interconnection and to guarantee important benefits. Future research directions are then presented towards a fully converged 5G IoT ecosystem. In this paper, we analyze existing data about D2D communication systems and its relation of 5G IoT networks. The enhancement of such networks will bring several spheres to learn for.

KEYWORDS: *device-to-device (D2D) communication; device discovery; interference management; power control; security; mode selection*

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I. INTRODUCTION

Device-to-device (D2D) communication is a direct means of communication between devices without an intermediate node, and it helps to expand cell coverage and to increase radio frequency reuse in a 5G network. Moreover, D2D communication is a core technology of 5G vehicle-to-everything (V2X) communication, which is an essential technology for autonomous driving. Moreover, when IoT technology emerges with 5G networks in massive machine type communication (mMTC) and ultra-reliable low latency communication (URLLC) application scenarios, these security challenges are more crucial and harder to mitigate because of the resource-constrained nature of IoT devices. To solve the security challenges in a 5G IoT environment, we need a lightweight and secure D2D communication system that can provide secure authentication, data confidentiality/integrity and anonymity.

II. RELATION BETWEEN 5G NETWORKS AND D2D COMMUNICATION

The Fourth Industrial Revolution or simply 'Industry 4.00' is how manufacturing industry expects to maximise the innovations of 5G wireless communications by automating industrial technologies and utilising other enabling technologies such as artificial intelligence (AI) and machine learning.

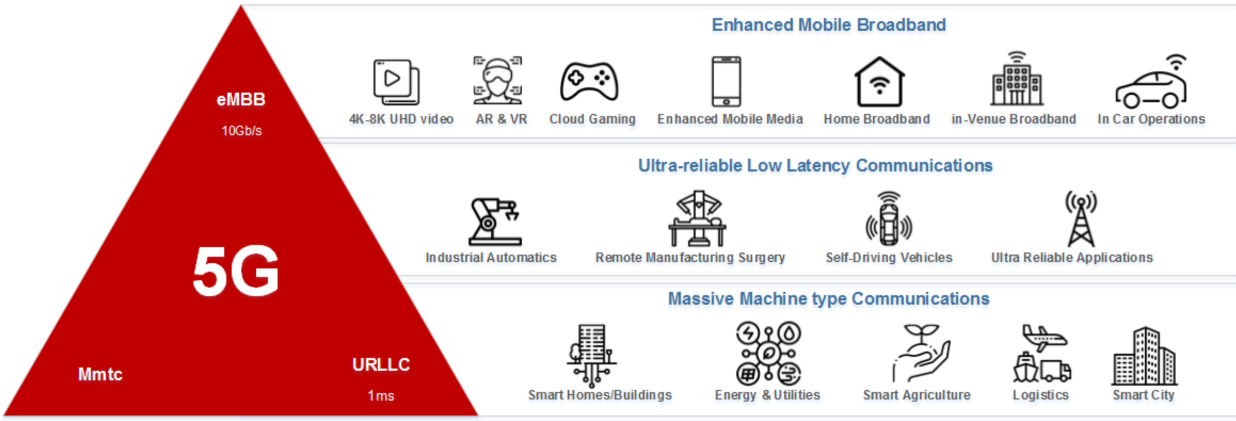

Figure 1.5 5G usages

Industry expects this to lead to more accurate decision making such as automation of physical tasks based on historical information and knowledge, or improved outcomes for a wide range of vertical marketplaces not just in manufacturing but verticals such as agriculture, supply chain logistics, healthcare, energy management and an ever-increasing number of industries becoming more aware of the potentials of 5G[7]. It is expected to achieve this in three ways through the use of network slicing, shown as Figure 1.5 above.

- eMBB (Enhanced Mobile Broadband)
- URLLC (Ultra-Reliable Low Latency Communications)
- mMTC (Massive Machine-Type Communications)

Enhanced Mobile Broadband (eMBB)

eMBB can initially be addressed by the expansion to existing 4G services as it aims to service more densely populated metropolitan centers with downlink speeds approaching 1 Gbps (gigabits-per-second) indoors, and 300 Mbps (megabits-per-second) outdoors. One way to accomplish this is through the installation of extremely high-frequency millimeter-wave (mm-Wave) antennas. For areas that are more urban outlying and beyond into rural setting areas, eMBB will work towards replacing 4G's current LTE (Long-Term Evolution) scheme, with a new network of lower-power omnidirectional antennas providing 50 Mbps downlink service. eMBB traffic can be deemed to be an addition to the 4G broadband service currently available. It is capable of large payloads and a by-a-device activation pattern that is capable of remaining stable over an extended time interval. This allows the network to schedule wireless resources to the eMBB enabled devices such that no two eMBB devices compete or access the same resource simultaneously.

Ultra-Reliable and Low-Latency Communications (URLLC)

URLLC can address critical needs of communications where bandwidth is not quite as crucial as speed, e.g., an end-to-end latency of 1 ms or less. The design of a low-latency and high-reliability service involves several components, including, incredibly fast data turnaround, efficient control and data resource sharing, grant-free based uplink transmission, and advanced channel coding schemes. Uplink grant-free structures guarantee a reduction in user equipment (UE) latency transmission by avoiding the middle-man process of acquiring a dedicated scheduling grant. These services are supported by the 5G New Radio (NR) standard. URLLC should be the tier that addresses the autonomous vehicle category, where decision time for a reaction to a possible accident needs to be almost non-existent. URLLC makes 5G a possible competing solution with satellite, for Global Positioning System (GPS) geolocation services.

Massive Machine-Type Communications (mMTC)

5G offers massive machine-type communication (mMTC), which aims to support tens of billions of network-enabled devices to be wirelessly connected[8]. Today's communication systems already serve many MTC applications. However, the characteristic properties of mMTC, i.e., the massive number of devices and the tiny payload sizes, require novel approaches and concepts. 5G allows a density of one million devices per square kilometer. 5G will be able to carry a lot more data and transfer it much faster than 4G LTE, however, faster is not always better or even necessary in the Internet of Things (IoT) world, especially when it typically requires more power on the end device. So the 5G NR standard will introduce new device types, like Cat-M1 (operates at 1.4 MHz bandwidth) and narrow band (NB-IoT).

Infrastructure Requirements for 5G

Attempts have been made to characterize the broad set of requirements of industrial automation. The integration of 5G to an existing network architecture will require the addition of an onsite 5G network comprised of macro or small cells, which will need to be fully IP-enabled. If an existing private 4G network is in situ, the 4G backhaul network can be reused whenever available and possible, but backhaul capacity will likely need to be upgraded since the 5G network delivers far more traffic than any cellular network did before. 5G mobile networks will significantly affect both the wireless side and the wired side of network infrastructure requirements due to the increased data traversing to and from the wired and wireless networks[9]. The smart factory is represented below in Figure 1.6 by being divided into several layers with different network choices at each layer; each network has different demands and rates the importance of various properties differently. It is decisions at each of these levels that will dictate the level of integration that 5G can bring to manufacturing. The key new concept of network slicing in 5G will enable tenants to gain different levels of connectivity from their service provider to accommodate various use cases.

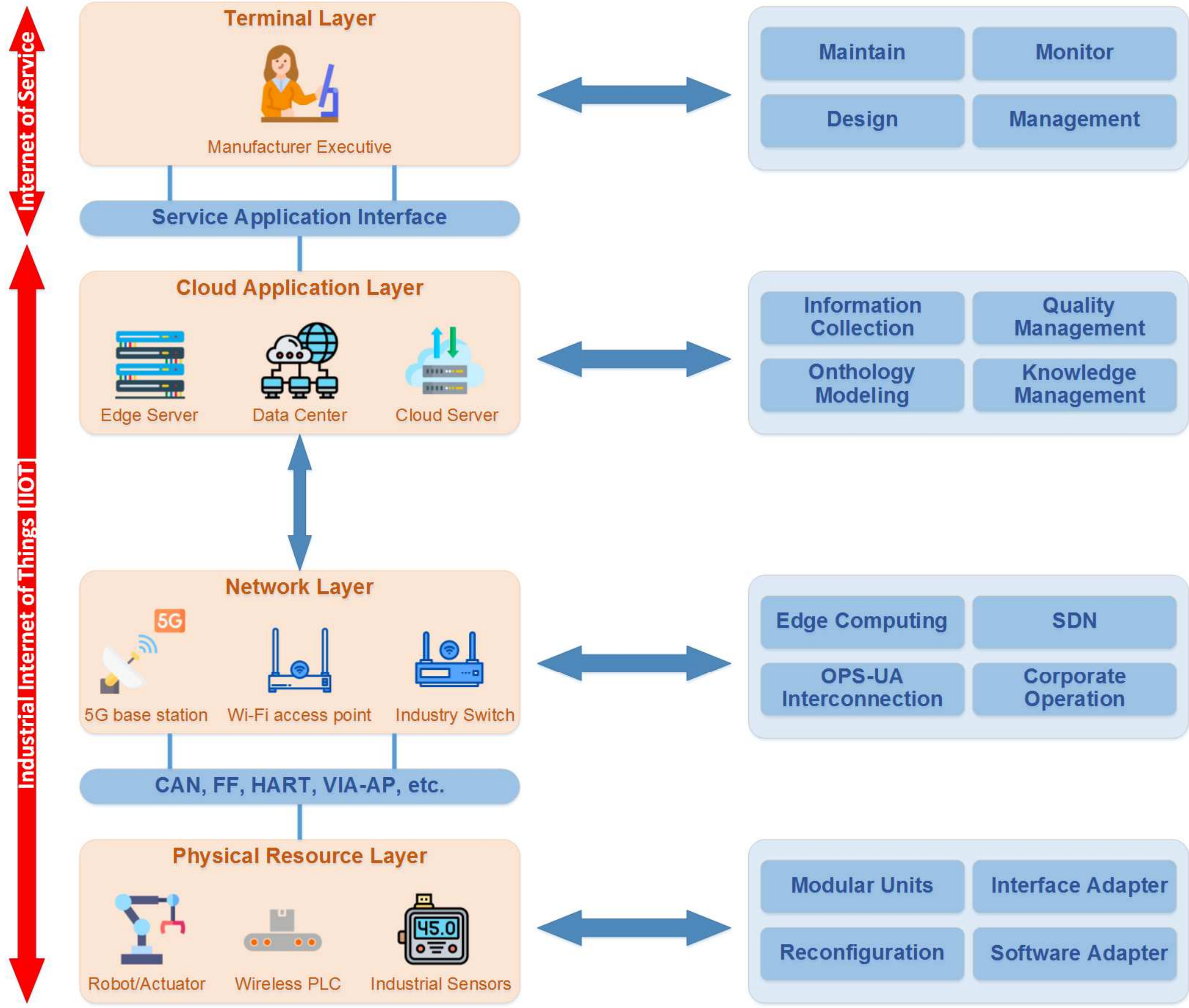

Figure 1.6 Hierarchical architecture for smart factory

Future 5G networks will have to provide a significantly higher system capacity than today and solve the anticipated spectrum crunch. There will be many infrastructure improvements required to provide a 5G network within a manufacturing environment. Requirements will range from theupgrading of backbone infrastructure within the organization to managing the utilization of the following:

- Spectrum adoption;
- Fiber rollout internally (10 Gb minimally);
- High-speed switches and routers;
- On-site computing;
- High-speed uplink to cloud computing facilities;
- Deploying edge-connecting devices.

5G in a Heterogeneous Network Infrastructure

Future 5G networks will have to provide a significantly higher system capacity than today and solve the anticipated spectrum crunch. Communications regulators globally are managing the allocation of spectrum for 5G usage; typically, the spectrum is being auctioned to telephone companies (Telcos) who are then offering a range of solutions to industry. In Europe, three major frequency bands have been made available for 5G use.

These three bands are 700 MHz, 3.6 GHz and 26 GHz. It should be noted that spectrum regulators in some countries have started the process of opening up shared spectrum for local use in specific bands, which will enable the deployment of private 5G networks and enable easier research and development deployments. In addition to cellular advances, Wi-Fi networking is also getting significant upgrades and this supplementing technology will add to the 5G ecosystem. Each technology offers individual improvements; they will also work in tandem to fill in gaps in environments where other technologies may not be ideal. The Wi-Fi Alliance is referring to the IEEE 802.11ax specification as Wi-Fi 6 because it's the sixth generation of Wi-Fi.

Fog and Edge Computing

Edge computing is currently being implemented in many industries utilizing the industry backbone for data management known as the programmable logic controller (PLC). The main task of a PLC is to acquire data from field devices, apply logic or arithmetic functions and set output values based on these computations. This typically requires round-trip times in the range of several microseconds to milliseconds. With the use of 5G networks, the rate at which instructions are processed by edge networks will increase with the flow of more considerable amounts of data. Fog computing brings intelligence to the shop floor network; edge computing brings intelligence, processing power, and communication capabilities directly into devices such as smart sensors and gateway devices [8].

A. Edge Computing
B. Multi-Access Edge Computing (MEC)

The Wireless Spectrum and 5G

With the rapid development of wireless communication technologies, the need for bandwidth is increasing. Usage of the wireless spectrum has increased in recent years and that has resulted in the necessity to manage the spectrum to allow multiple end-user devices to communicate in a structuredmethod enabling interoperability across a wide array of wireless protocols both presently available and those that are due for release in the near future.

III. RELATION BETWEEN IOT AND D2D COMMUNICATION

The Internet of Things (IoT) holds the promise to improve our lives by introducing innovative services conceived for a wide range of application domains: from industrial automation to home appliances, from healthcare to consumer electronics, and many others facing several societal challenges in various everyday-life human contexts (Figure 1.7). Currently we have 10 billion IoT devices connected and 24 billion to 50 billion total connections expected within the next five years. The vision of a "smart world" where our everyday furniture, food containers, and paper documents accessing the Internet is not a mirage anymore! The IoT growth is sustained by the constant increase in the number of devices able to monitor and process information from the physical world and by their decreasing costs. Most of them operate through their virtual representations within a digital overlay information system that is built over the physical world. The majority of current IoT solutions, indeed, requires Cloud services, leveraging on their virtually unlimited capabilities to effectively exploit the potential of massive tiny sensors and actuators towards a so-called Cloud of Things [7].

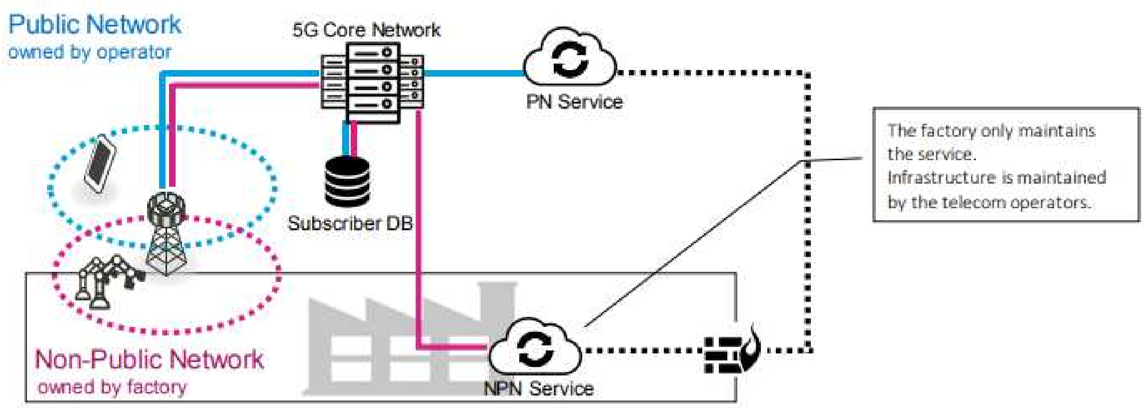

Figure 1.7 Whole deployment picture: Public Network integrated Non-Public

Recently, also long-range cellular networks are being considered as promising candidates to guarantee the desired internetworking of IoT devices, thanks to the offered benefits in terms of enhanced coverage, high data rate, low latency, low cost per bit, high spectrum efficiency, etc. [3]. Furthermore, the Third Generation Partnership Project (3GPP) has introduced novel features to support machine-type communications† (MTC) [6] by accounting for the intrinsic battery-constrained capabilities of IoT devices and the related traffic patterns (e.g., small data packets). 5G will not only be a sheer evolution of the current network generations but, more significantly, a revolution in the information and communication technology field with innovative network features [9]. Among these we can mention:

1. native support of MTC, according to which ad-hoc transmission procedures are defined to efficiently handle the cellular transmission of small packets by reducing latency and energy consumption;
2. small-cell deployments, envisaging femto, pico and relay cells massively deployed to extend coverage and capacity and to reduce energy consumption;
3. interoperability, i.e., seamless integration between 3GPP and non-3GPP access technologies to enhance reliability and coverage;
4. optimized access/core segments, achieved through novel paradigms such as softwarisation and virtualization of network entities and functionalities, respectively. In this direction go the initiatives of GSM Association towards embedded-sim (esim) solutions, to overcome the classic concept of physical cellular sim, which could be a serious limitation for large-scale tiny IoT device (e.g., sensors). The e-sims will allow "over the air" provisioning of network connectivity and possibility to subscribe to multiple operators.

In the evolutionary scenario depicted so far, a new device-to-device (D2D) will play an undoubted key role in the IoT/5G integration [7]. D2D communications refers to the paradigm where devices communicate directly with each other without routing the data paths through a network infrastructure. In wireless scenarios this means bypassing the base station (BS) or access point (AP) and relaying on direct inter-device connections established over either cellular resources or alternative over WiFi/Bluetooth technologies. This approach has recently gained momentum as a means to extend the coverage and overcome the limitations of conventional cellular systems.

IV. CONCLUSION

The aim of this chapter is precisely to discuss the infrastructure introduced by D2D technologies that may be suitably exploited within IoT ecosystems operating within future 5G systems. In detail, the expected contributions are:

1. highlighting the main features of D2D communications that may come in handy to fulfil the requirements of IoT;
2. discussing the state of the art on D2D-enabled solutions and analysing possible enhancements to further boost the performance of D2D communications in IoT environments;
3. introducing promising future trends and identifying relevant IoT research areas by assessing the role ofD2D communications to accomplish the view of a fully integrated 5G IoT ecosystem.

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