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5G Technology in the Internet of Things: Capabilities, Limitations and Design Considerations

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Abstract: *When implementing 5G mobile networks to integrate into the internet of things, there are a lot of exciting and headline grabbing capabilities such as increased connectivity, low latency and high data rates. This paper discusses how 5G can support different needs of the IoT with enhanced mobile broadband, massive machine type communications and ultra reliable low latency communications. It also looks at features such as edge computing, network slicing, private networks and the Reduced Capability (RedCap) devices. This work uses a narrative review of standards and peer reviewed literature to examine how 5G can best be used. This shows that 5G has most benefit when there is a specific reason why wide area mobility, quality of service and/or local computing is needed. It may not always be a low cost, low power solution for simple sensors. Coverage, power usage, interoperability, cost throughout the lifetime of the IoT and security must also be considered. This paper provides a framework for choosing a solution and areas to research for more realistic 5G IoT implementations.*

Keywords: 5G, Internet of Things, Industrial IoT, RedCap, Network Slicing, Edge Computing

I. INTRODUCTION

The internet of things has been developed using a variety of different networks. Different devices need different communication capabilities such as a temperature sensor in the field, wearable health monitoring device or mobile robot on a factory floor. The 5G mobile networks are relevant to the IoT since they provide a cellular network that can support many services such as high data rate broadband, large number of low data rate devices and low-latency, high reliability [1][2]. 5G is a flexible option for IoT implementations however it is important to consider if it fits with your application.

This paper aims to identify when the 5G will improve the IoT system and what trade-offs you should expect. Key capabilities of 5G are discussed along with examples of applications. Limitations are also identified, and these can sometimes be overlooked when looking at performance targets. This work uses a narrative review of peer reviewed surveys and 3GPP related material. This doesn't aim to test the performance of 5G however it does provide a framework for designing your system.

II. REVIEW METHOD

This review looked at peer reviewed survey papers related to 5G IoT, massive access, industrial IoT and security. 3GPP related material was also used to provide information on industrial IoT and Reduced Capability devices [1]-[6]. The sources picked were relevant to the architecture, use case and constraints. The findings are framed around a design focus. Due to the dependence on spectrum, radio, device and configuration, the performance targets aren't guaranteed.

There are three general categories for services provided by 5G. Enhanced mobile broadband (eMBB) provides high data rate applications such as cameras and augmented reality. Massive Machine Type Communication (mMTC) is for a large amount of devices sending small bursts of data. Ultra Reliable Low Latency Communication (URLLC) is for

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applications where timing and reliability is important such as some industrial control applications [1][2]. These are just names for the requirements. An IoT project could include more than one of these.

II. HOW 5G CAN SUPPORT IOT

A. Different Device Types

An advantage of 5G is that it can support a variety of different device types. A camera may have a requirement for high uplink data rates whereas a utility meter may only have a requirement for small data bursts. Massive access research shows that it can be challenging to support devices sending small bursts of data at scale [3]. Just because it is 5G doesn't mean there won't be any congestion issues.

Reduced Capability (RedCap) has been introduced in 3GPP release 17 to provide a reduction in complexity and capability for devices that aren't as simple as a sensor but not as complex as a 5G phone. This helps provide a better gradient of device types however there will still be considerations around cost, battery life and network availability depending on the implementation and local deployment. Narrowband IoT and LTE-M are still relevant options to consider for low power wide area devices.

B. Low latency and Local Processing

Having low latency in the radio is only useful if the rest of your system can support it. An industrial control message may go through several processes including the device, radio, core network, application server and control logic. This may mean that the latency isn't as low as expected. Multi Access Edge Computing can place some of the processing closer to the radio network, reducing the distance data travels and providing local processing [4]. This also means less raw data from the sensors need to be sent to the cloud. However edge platforms do have their own considerations in terms of software maintenance, physical security, redundancy and integration with the central system.

With URLLC there will be specific test scenarios, packet sizes, scheduling and network setup that provide the reliability and latency figures. When designing a safety critical system you should aim to have a system that has been tested for end to end performance and a safe response to communication failure. Don't assume it will be safe because the radio has a target latency [2][4].

C. Network Slicing

Network slicing can help provide resources for different service requirements. A private 5G network can give more control over local coverage. For example in a factory you may have a private network so that your mobile equipment, inspection cameras and sensors can be connected. This will depend on whether the organisation can plan, run and secure the network. Network slicing is a method for managing resources but can't guarantee it won't be affected by any failures or threats. Interoperability can be an issue with existing industrial equipment and skilled support is required [4][6].

IV. APPLICATIONS AND TRADE-OFFS

A. Industrial Monitoring and Control

Factories are a good candidate for 5G if it is difficult to install cabling, assets are mobile or high data rate sensing needs to be added without changing the production line. Cameras can be used for visual inspection and mobile robots can benefit from having a quality of service wireless network. Many control loops already have reliable connections using industrial ethernet or specialist wireless. Only if there is a reason to have a mobile, reconfigurable or other measurable benefit should you consider 5G. Interoperability, security and verifying quality of service targets are identified as issues when researching industrial 5G [4][6].

B. Healthcare and Connected Transport

5G can be used to transfer high resolution imaging data. Mobile equipment can be connected across the campus. Wearable sensors may benefit from having wide area connectivity however many can function adequately using Bluetooth or other low power options to connect to a phone/gateway. Connected vehicles and roadside infrastructure

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may need to share time sensitive data. However consideration should be given to coverage changes, congestion and what happens if a message isn't received. 5G will be one element of a bigger system.

C. Selecting the Right Connection

Start by thinking about your application. Document the message size and frequency, mobility requirements, coverage area, acceptable latency, what happens if packets are lost, battery target and expected device life. If you only have a requirement for occasional low data rate readings then a cheaper low power option may be better. If you do need a mobile broadband, quality of service or local wide area connectivity then 5G may be a better option. You should do a pilot to understand the end to end latency, packet delivery, handover, power consumption and maintenance.

V. CHALLENGES AND AREAS FOR RESEARCH

Power and cost can be an issue. Devices may have a shorter battery life due to frequent radio wake ups, multiple attempts to connect and poor coverage. More capable devices may be more expensive and have more complex certification and support requirements. RedCap has been developed to bridge the gap between full 5G devices and simpler IoT radios however it needs to be proven that it will be cost effective for the product and deployment [5]. Future studies should include power usage on the device and network throughput so comparisons can be made fairly.

Security is an overall consideration. Cellular authentication and network security can be useful however if the sensor hasn't been configured well, the management interface is open or the application holds onto data unnecessarily then this won't be secure. You should ensure that the devices have identities, secure updates, least privilege, monitoring and a plan for devices that can no longer be patched. Privacy and security are highlighted as ongoing issues when researching 5G-IoT [7]. Testing on resource constrained devices and multi vendor systems would be beneficial.

Evidence of deployment can be an issue. It can be difficult to replicate results from the lab as there will be varying levels of interference, mobility and operational traffic. More longitudinal studies should be done to compare private and public networks, quantify cost throughout the device lifetime and provide information on how the service performs in fault scenarios. This will help organisations understand if there is a real benefit to using 5G for their application.

VI. CONCLUSION

5G provides more options to IoT designers. It can support a wide area network with broadband, massive device access and time sensitive communications. Edge computing, network slicing, private networks and RedCap can all help provide flexibility. It is important to consider that 5G will only be useful if you have a requirement for mobility, quality of service or local network. It isn't a default upgrade for all sensors. Careful design will help compare the options and test the whole system in realistic scenarios. Energy, security, interoperability and operational costs are key requirements. More evidence from the field will help make future decisions on 5G-IoT more reliable.

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