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Massive IoT: Emerging technologies

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The number of connected "things" worldwide dramatically increases, with dozens of billions smart objects or devices already in use. Internet of Things (IoT) is an evolution from Machine-to-Machine (M2M), with the latter being a rudimentary form of connecting machines for simple tasks such as starting a vehicle remotely. It is widely believed that IoT will be a key business driver for telecommunication service providers and enterprises in the coming years. More recently, there has been an emerging IoT term defined as Massive IoT (MIoT), referring to the tens of billions of devices, objects, and machines that require ubiquitous connectivity even in the most remote locations, like sensors buried deep in the ground, and that report their sensing data to the cloud on a regular basis. To reach massive scale, which is defined by 3GPP as at least 1 million devices per kilometer, mobile networks must more efficiently support the simplest devices that communicate infrequently, and are ultra-energy efficient so they can deliver an extremely long ten-year battery life. The requirement would be for low-cost devices with low energy consumption and excellent coverage. The growing popularity of IoT use cases in domains that rely on connectivity spanning large areas, and able to handle a huge number of connections, has driven up the demand for massive IoT technologies.

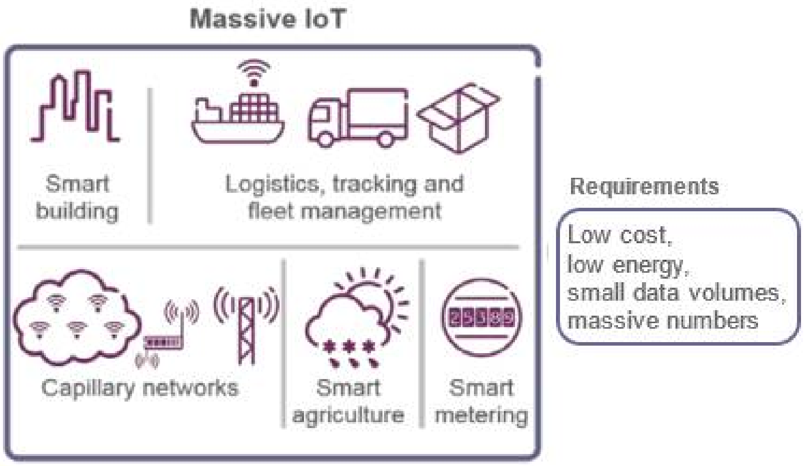

Figure 1. Massive IoT applications and requirements

Along with the rapid growth of the IoT market, Low Power Wide Area Networks (LPWAN) have become a popular low-rate long-range radio communication technology. LPWAN is a solution of low-energy wireless communication compared to M2M cellular networks in terms of energy consumption and hardware complexity. There has been the emergence of new technologies in the last few years, such as Sigfox, LoRa and NB-IoT that are suitable for deploying massive IoT applications. While the technologies like Sigfox and LoRa are gaining market attention, 3GPP-supported cellular-based NB-IoT is catching up and by 2020, narrowband Internet of Things (NB-IoT) will become the dominant standard for LPWAN.

	LoRA	Sigfox	NB-IoT
Band	868/915 MHz	868/915 MHz	LTE Band
PHY	CSS	UNB	NB
Spreading Factor	$2^7 - 2^{12}$	--	--
Bandwidth	500-125 KHz	1 KHz	180 KHz
Data rate (Kbps)	27-0.37	0.1	250-226.7
Range (Km)	22	63	35

Table 1. Specifications of emerging massive IoT technologies

These new technologies have been optimized to provide excellent range while lowering power consumption. They are able to connect tens of thousands of devices, covering hundreds of square kilometers, using just one base station or gateway. When the increasing numbers of devices become connected, we will see more and more dense applications appearing across all verticals. These will evolve towards massive IoT, with increased communication between devices and higher density levels than we have ever seen before.

There are new technologies being developed to specifically address the need for high density connections. 5G has defined mMTC (massive Machine Type Communication) as one of the most notable technology that met the generic Massive IoT requirements. 5G will utilize streamlined signaling protocols and a lean but flexible air interface to facilitate the deployment of massive IoT in ultra-wide areas with ultra-high density.

Alternatively, wireless mesh technologies are the another options to connect densely deployed nodes. The principle of mesh networks is to rely on peer-to-peer communication between nodes to exchange information or forward data to and from a gateway. Thanks to recent advancements in networking protocols and the reduced cost of nodes, the ability of wireless mesh networks has been greatly enhanced to cover wider areas.

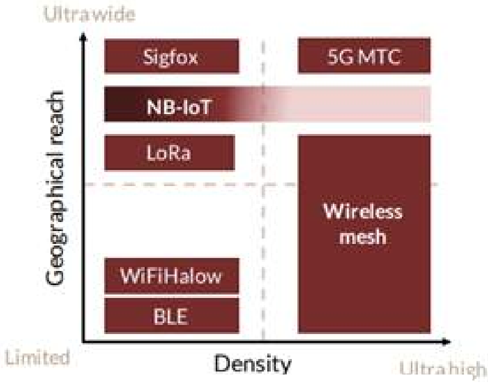

Figure 2. Massive IoT technologies: geographical reach vs. node density

One of the most important aspects for IoT devices is energy efficiency since many devices are energy-constrained (i.e battery-powered devices) and communicate using a relatively energy-demanding radio. Fortunately, MAC layer technologies can address the problem effectively and hence years battery life time may be achieved.

MAC technologies use optimizing mechanisms that can avoid issues such as collision, idle listening, over hearing and re-transmission. Radio duty cycling is fundamental to low-power wireless, in which the radio can be turned off most of the time when it is not needed. As a result, energy efficiency can be improved significantly. Hence MAC layer technologies play a major role in reducing of power consumption of the system and are used for massive IoT applications. Some of the efficient MAC protocols are Power-aware Multi-access Protocol with Signaling (PAMAS), synchronous MAC (S-MAC, T-MAC, SCP-MAC), asynchronous MAC (XMAC, ContikiMAC), etc. The IEEE has standardized different protocols for radio duty cycling, namely, Coordinated Sampled Listening (CSL) and Time-Slotted Channel Hopping (TSCH). Some state-of-the-art MAC protocols have already been applied in IoT operating systems such as TiniOS, ContikiOS.

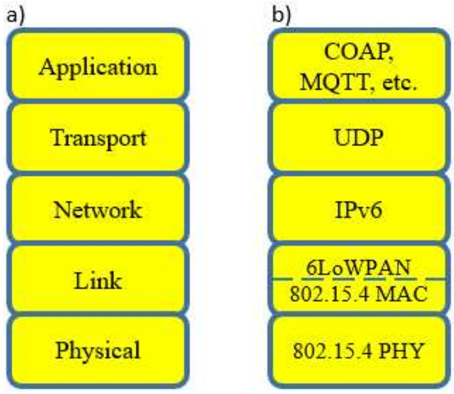

Figure 3. Network layers for IoT

6LoWPAN is an open IoT networking protocol that is specified by the Internet Engineering Task Force (IETF). It creates an adaptation mechanism between IPv6 in layer 3 and the 802.15.4 Mac layer 2. In IoT network, 6LoWPAN has an important role in making compatible between IPv6 and IPv4 devices. The more IoT grows in the connected things era, the greater new networking technologies keep the huge role.

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